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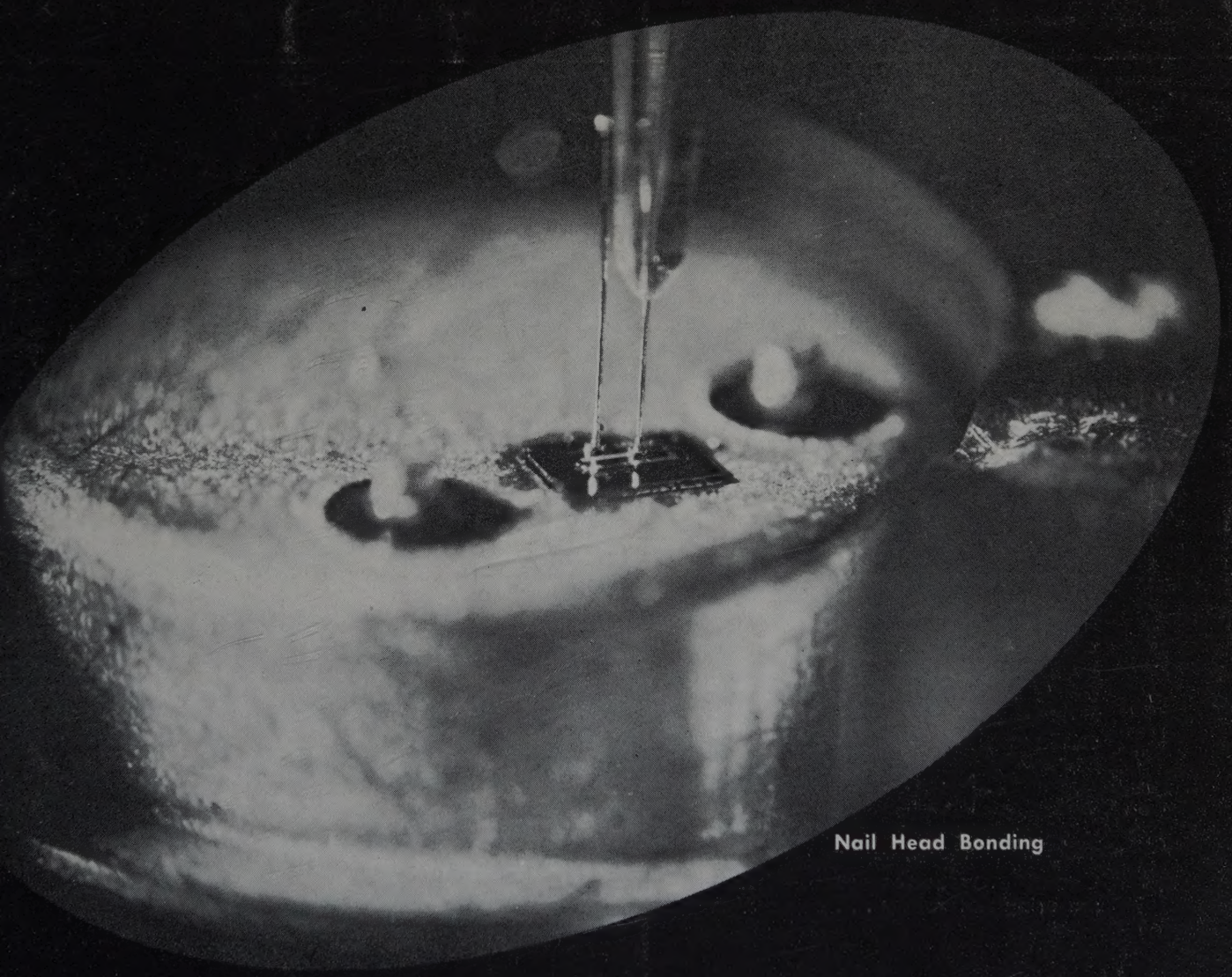


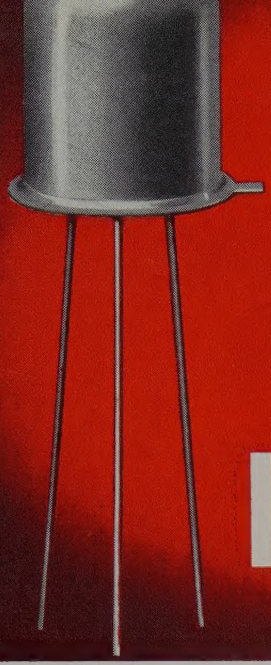
Nail Head Bonding

A New Concept in Transistor Converters

Switching Time Formulae

Hall Effect Multipliers

Industry Report



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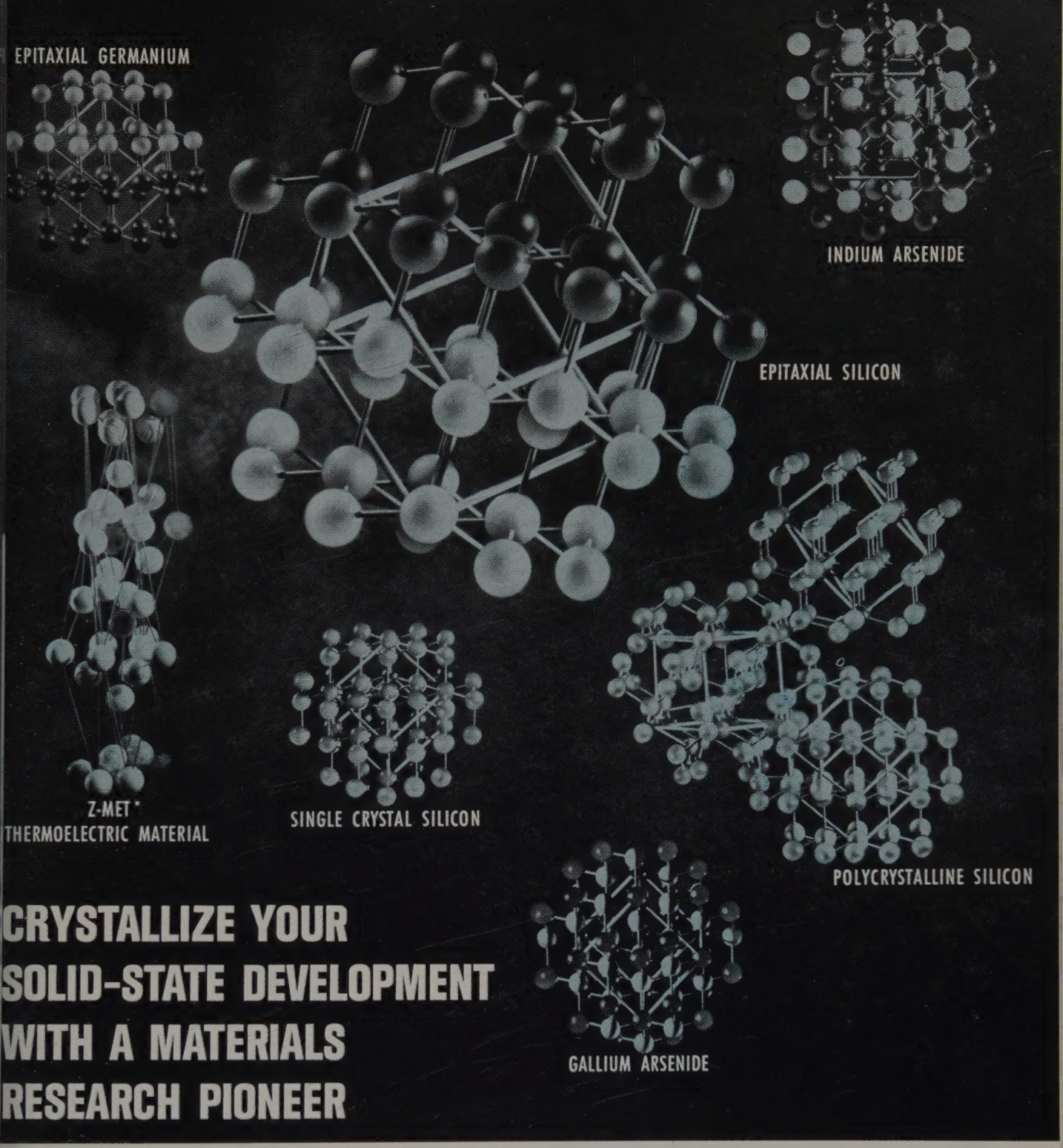

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

June 1961 Vol. 4 No.

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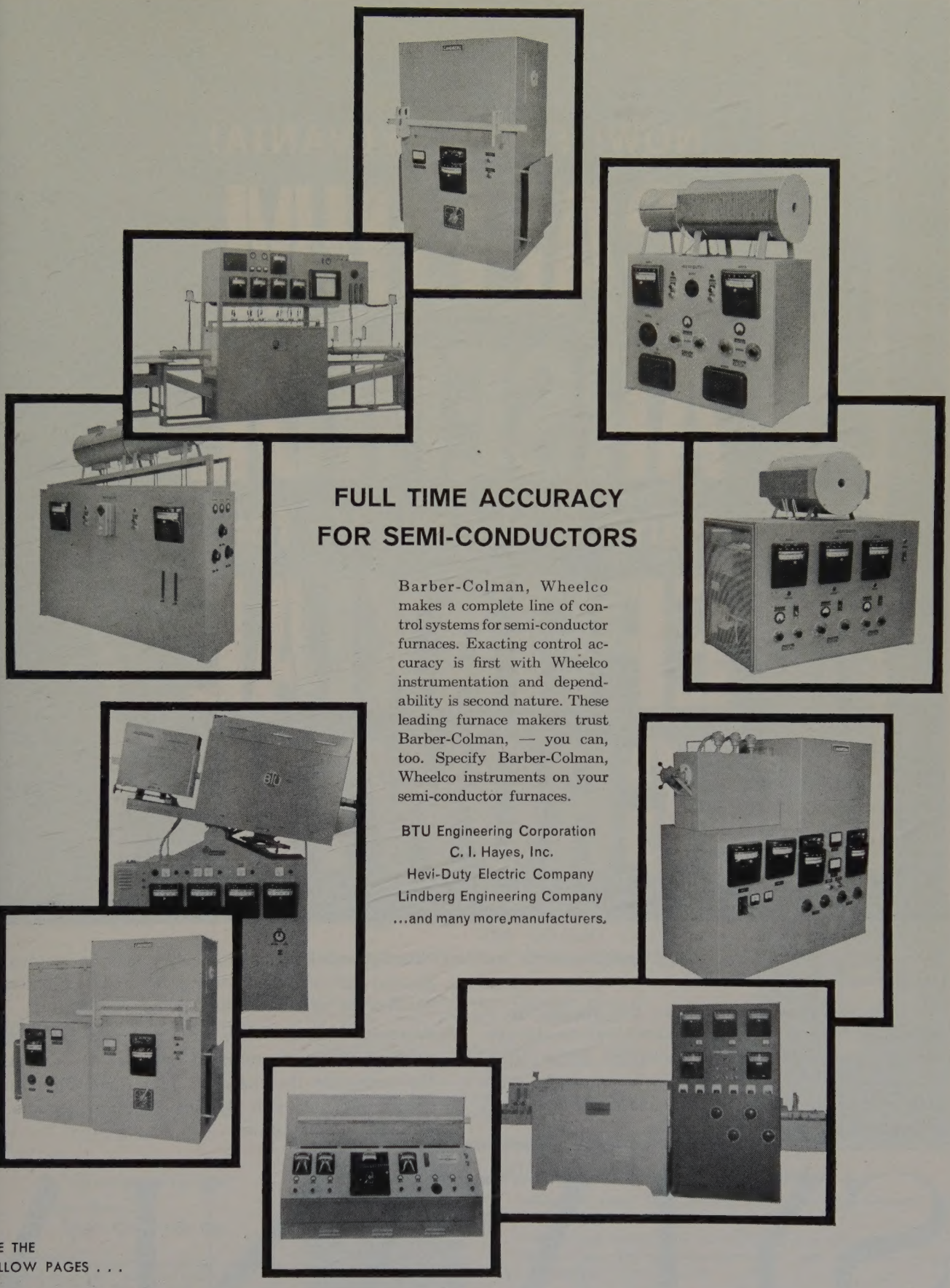
Front Cover

K&S Model 442 Nail Head Bonder in operation, showing second bond being made to geometry on pellet of a semiconductor. Note ball at top of first bonded wire. When hydrogen flame-off burner severed wire automatically at conclusion of this first bond, a similar ball was formed at the lower end of wire extending from automatic feed. This ball (or nail head) was used to make second bond to semiconductor pellet. In an instant after this macrophotograph was taken, wire feed nozzle had automatically risen clear of first bonded wire's height and flame-off had automatically severed second wire forming similar balls on each of the severed ends. Equipment is designed and built by Kulicke and Soffa Manufacturing Company, Philadelphia, Pa.



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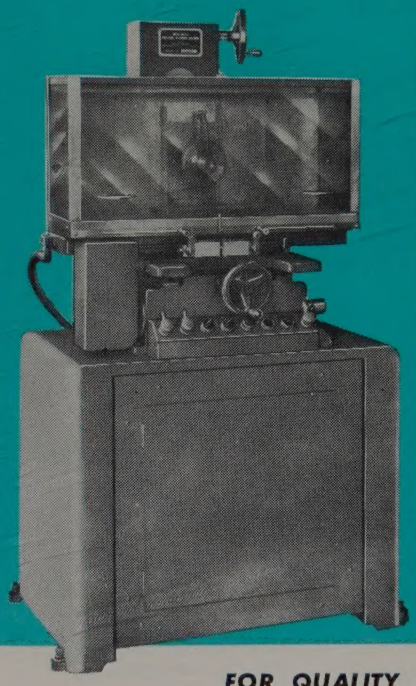

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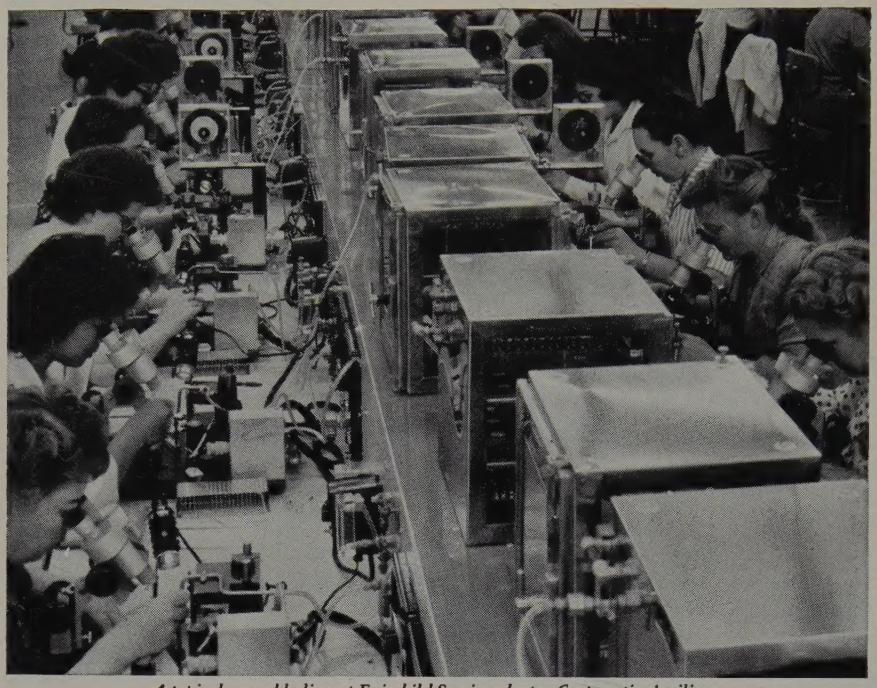

A typical assembly line at Fairchild Semiconductor Corporation's silicon transistor plant in Mountain View, California.

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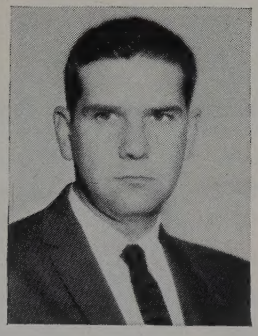

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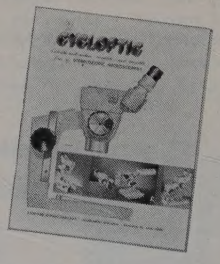

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Book

TITLE: Industrial Electric Furnaces and Appliances, Second Edition

AUTHORS: V. Paschkis and John Persson

PUBLISHER: Interscience Publishers, New York

This book begins with the incontrovertable statement that "One kilowatt hour—of electrical energy—is the equivalent of 3413 BTU." The remainder of the book exploits the ramifications of this fact as this pertains to the industrial heating of materials. The fact that so much industrial processing is dependent on elevated temperatures in order to achieve certain physical, chemical, or physical-chemical consequences strongly underlines the situation that our engineering schools give all too little emphasis to the design and principles of operation of the primary tool of heat treatment, the furnace. On the other hand, here is one discipline where with an average Bachelor's Degree in almost any field of engineering, a man may become relatively "an expert" by application to a book such as the subject of this review. The subject matter in this case is sufficiently simple that self-study is a practical pursuit which should yield to any engineer who has a heating process under his purveyance a quick technological and economical advantage.

An initial chapter of about 100 pages on heat transfer with emphasis on conduction, convection, and radiation and how they may be used to heat a furnace charge is boiled down to charts from which one may lift quantitative facts about surface temperature vs. center temperature of the work, heat losses through furnace walls, temperature distributions in furnace walls, etc. This section is liberally illustrated with sample calculations using these charts. A chapter on arc furnaces is well presented but is probably of little interest to people in the semiconductor industry. On the other hand, the chapter on resistance heating is of great value as is the portion on induction and dielectric heating.

An effective presentation is made throughout, also, on the subjects of temperature controllers, conveyorizing, and the economics of furnace selection and operation.

This book is strongly recommended as text and reference.

By George Freedman

eviews...

TLE: An Outline of United States tent Law

THORS: Richard Brink, Donald Gip-, Harold Hughesdon

BLISHER: Interscience Publishers, w York

An Outline of United States Patent Law a very useful and basic book for the sign engineer and engineering execu-e. All too often the legal aspects of gineering are overlooked, especially in tent work.

The usefulness of a patent law book to e engineer rests solely in the presenta-n of material and in that respect this lume is excellent.

The material is divided into nine chap-rs, each pertaining to a special aspect patent law, e.g., preparation of an ap-ication, filing, interference, review of cisions, etc.

A very novel question and answer tech-que is used to introduce the concept a patent in Chapter I. The next chap-r modifies this technique by eliminat-g the questioning and describing the rocedures and requirements necessary prepare an application. In a similar anner filing, modification and interfer-ce (priority of claim determination) are vered in the next chapters. The margin tes along the text refer to paragraphs Title 35 of the United States Code re-rding patents.

Fully half of the book is devoted to an tensive bibliography consisting of four pendices referring to; Title 35 of the nited States Code, Rules of Practice, itation of Law and Foreign Practice. any classifications of the law are pre-nted and a very complete index com-etes the work.

An Outline of United States Patent Law an excellent, well-written guide to the nited States Patent system that should included in the library of every de-gn engineer.

By Stephen E. Lipsky

(Continued on next page)

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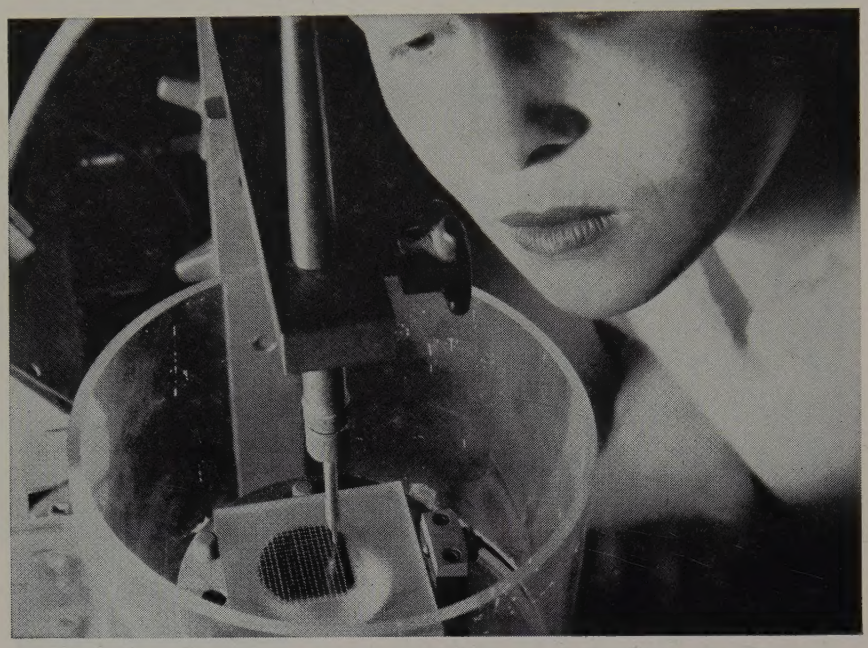

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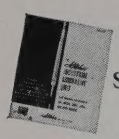

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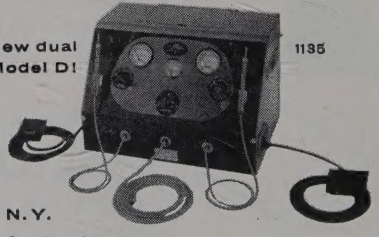

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Book Reviews

(continued)

TITLE: Noise In Electron Devices

AUTHORS: Edited by Louis Smullin and Herman Haus

PUBLISHER: The Technology Press of M.I.T., and John Wiley & Sons

Noise In Electron Devices is one of a series of excellent books published by the Technology Press of M.I.T. and represents the contributions of many authors, each an expert in his field of specialization.

Noise can be basically divided into two types, the Shot or Johnson noise and Flicker noise. Of the two, the shot noise phenomenon is the better understood. Chapter I is devoted to an analysis of shot noise from Thermionic cathodes. The temperature-limited diode is carefully analyzed and the formulation of the smoothing factor is developed. High frequency emission noise (non-negligible transit time) and smoothing factors are also discussed in detail.

Chapter II, written by A. Van der Ziel, is a detailed discussion of the Flicker effort or noise over and above shot noise as found in vacuum tubes at low frequencies. A characterization of the noise is made for two terminal networks (diodes) and for active four terminal networks (triodes, pentodes, etc.) The Schottky theory of flicker noise is stated and an analysis of this type of noise in triodes, pentodes and secondary-emission tubes is presented.

The book next discusses noise propagation along electron beams in chapter III and as a logical outgrowth develops the noise characteristics of grid-control tubes in chapter IV. The fifth chapter, written by R. W. Peter, discusses low-noise traveling-wave tubes in a very complete and detailed analysis. The last two chapters, VI and VII, are most interesting to the solid-state electronic circuit designer since they comprise one of the best presentations of the noise problems in semiconductors and transistors.

Noise In Electron Devices is an excellent, authoritative textbook providing a good source reference to many fundamental noise concepts and problem solutions.

By Stephen E. Lipsky

Book Reviews
(continued)

TLE: Electronic Processes in Solids

UTHOR: P. D. Aigrain, R. J. Coelbo, G. Scarelli

JBLISHER: Technology Press of M.I.T. nd John Wiley & Sons

Electronic Processes in Solids is a series notes based upon eight lectures given Dr. Aigrain, a visiting professor of ectrical Engineering at M.I.T. The book as prepared by Drs. Coelbo and Ascalli from their notes.

This book is a remarkably readable esentation of Atomic Physics oriented the solid state processes as ultimately plied to semiconductors.

The book proceeds with a consideration the electron core structure of a crystal ttice. The crystal Hamiltonian is prented and the Born-Oppenheimer aproximation is used as a first step solution. The Schrodinger equation for the mplified Hamiltonian is next solved. The athematics here are quite involved and ie authors presuppose a more than fundamental reader background.

The book continues to develop the elecronic wave equations and introduces onduction theory. The concepts of elecron motion and "hole" motion are covred quite well by comparison to simple echanical analogues. (p. 30).

A variety of other topics are well eated. Transport theory is presented in lementary form in Section 10. Photon cattering of electrons and non intrinsic cattering mechanisms are studied in ections 12 and 14. The book concludes ith a treatment of High-Field conduction phenomena in the last section.

Electronic Processes in Solids is an exellent book well recommended to the hysicist and advanced engineer. The oncepts are well presented and analyzed. his book will undoubtedly be useful in graduate study of semiconductor physcs and is well recommended to the serius student.

By Stephen E. Lipsky

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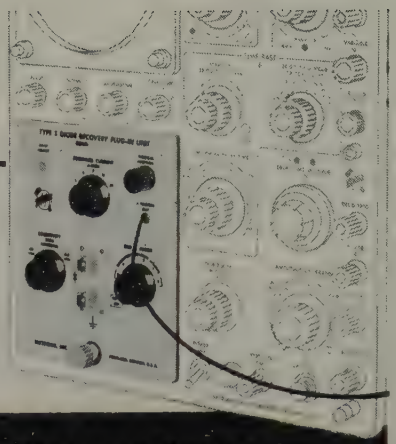
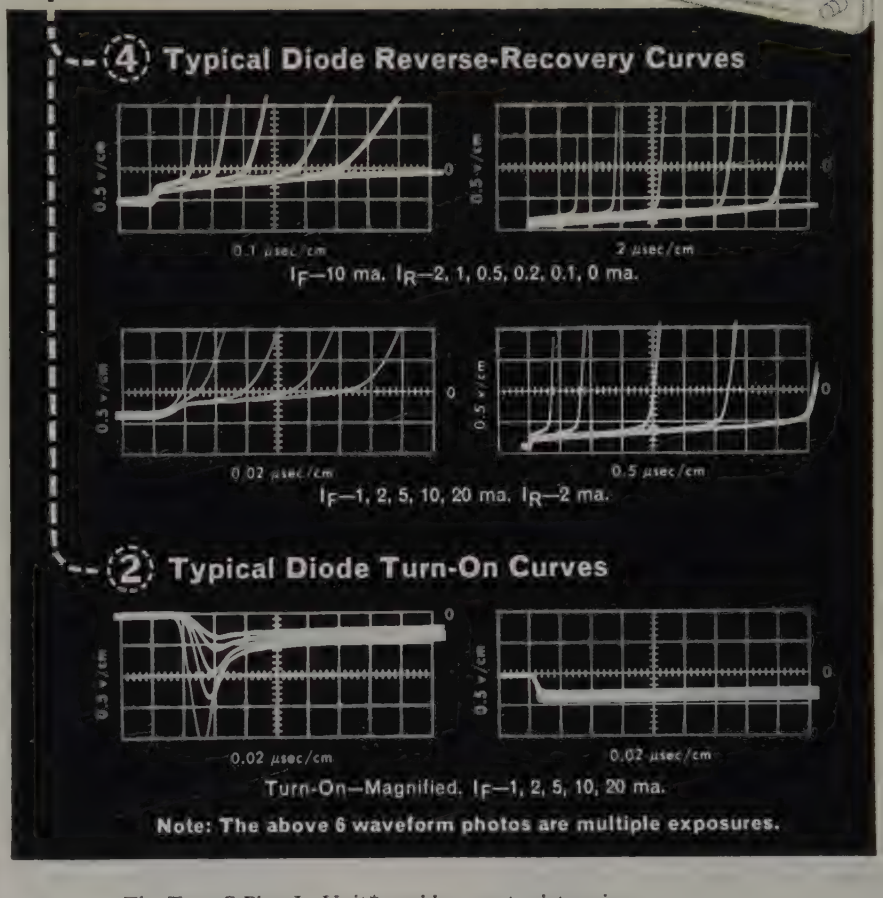
for displaying both forward and reverse switching characteristics of semiconductor diodes.




4 Typical Diode Reverse-Recovery Curves
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0.1 μsec/cm
2 μsec/cm
IF—10 ma. IR—2, 1, 0.5, 0.2, 0.1, 0 ma.
0.02 μsec/cm
0.5 μsec/cm
IF—1, 2, 5, 10, 20 ma. IR—2 ma.
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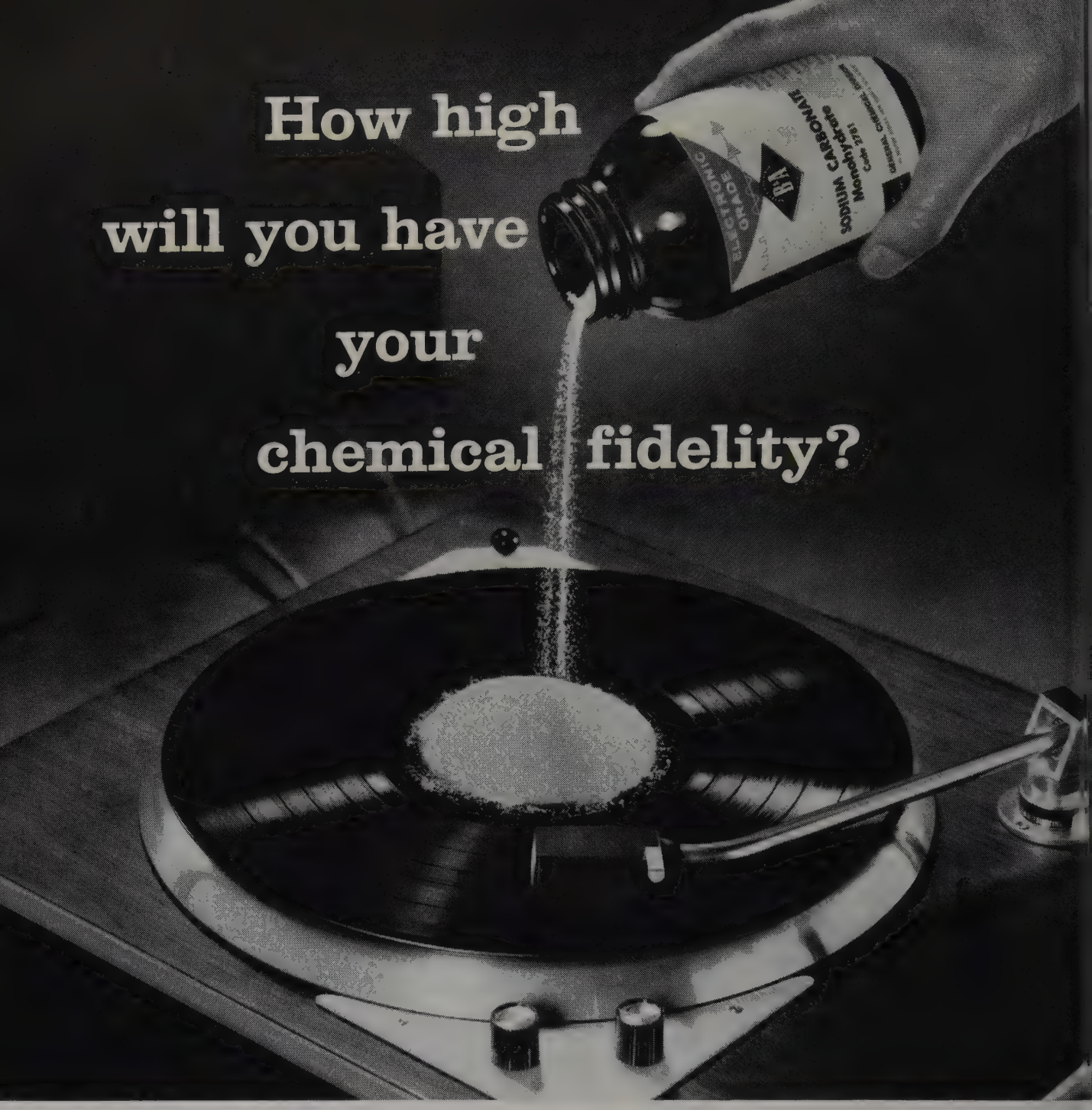

To be considered truly hi-fi, an amplifier's distortion at rated output should not exceed 1% at 20 CPS and 20,000 CPS. B&A® "Electronic-Grade" Chemicals meet standards far higher than these. Their maximum allowable impurities are limited to ten thousandths, even millionths of a *percent.*

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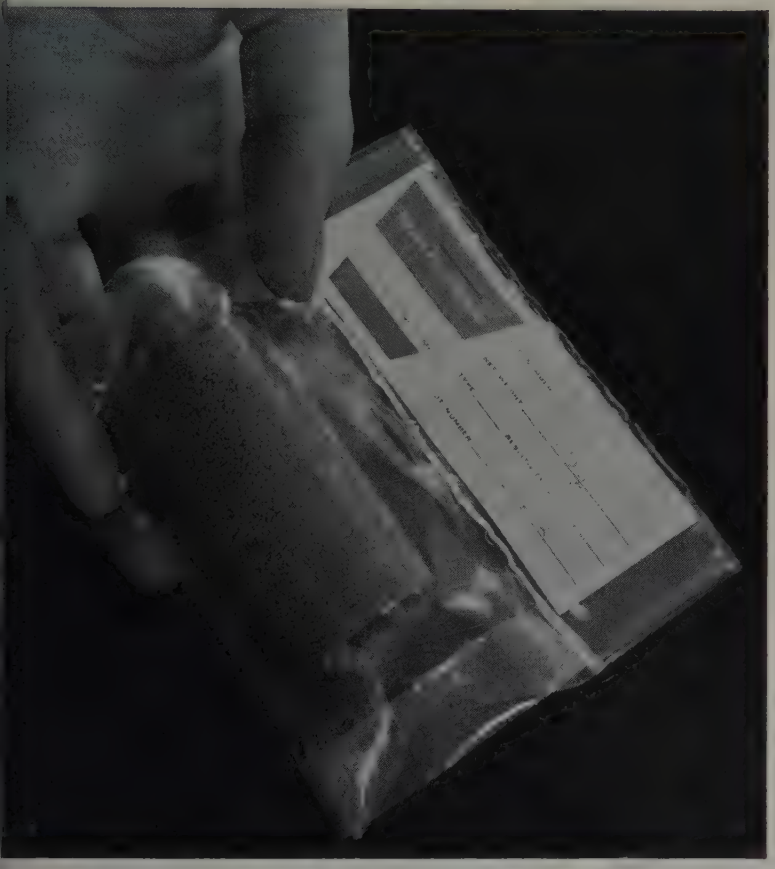
The Untouchables (Part 4)

Specify Crucible Charges of Deposited Hyper-Pure Silicon



Pre-packaged single piece crucible charges . . . in sizes and weights to meet the exact requirements of your Czochralski crystal growing equipment . . . are now available from Dow Corning.

Accurately Pre-weighed, these single piece crucible charges assure easy handling . . . smallest surface area . . . highest purity . . . an exceptionally clean melt and a savings in crucible costs.

High Quality is inherent in Dow Corning crucible charges. The *deposited* polycrystalline silicon in these charges has never touched a mold. Result — highest purity.

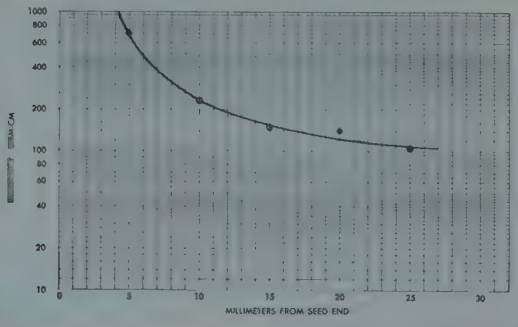
This High Purity means consistently higher quality crystals — simplifies doping procedures — increases device yield. Typical resistivity of N-type crystals grown from Dow Corning prepackaged crucible charges is greater than 100-ohms centimeter for 80% of the crystal; maximum boron content, 0.3 parts per billion atoms; maximum donor impurity, 2.0 parts per billion.

Now You Specify the Weight and Diameter, up to 38 mm (about 1½″), best suited for each crucible of your Czochralski crystal growing machines. Your crucible charges will be supplied in the appropriate length to provide the exact weight you require in just one piece.

Protective Packaging guards initial *deposited* purity right through crucible charging. Charges are individually wrapped in special cellophane, and sealed in airtight polyethylene envelopes to assure untouchable purity.

Whatever your need — deposited silicon crucible charges; polycrystalline rod or chunk; high resistivity P-type single crystal rod; single crystal rod doped to your specifications — Dow Corning should lead your list of sources.

Profile of Crystal Grown from Pre-Packaged Charge



Free brochure — "Hyper-Pure Silicon for Semiconductor Devices." Write Dept. 1818.

HYPER-PURE SILICON DIVISION
Address: HEMLOCK, MICHIGAN

Dow Corning CORPORATION
MIDLAND, MICHIGAN
ATLANTA BOSTON CHICAGO CLEVELAND DALLAS LOS ANGELES NEW YORK WASHINGTON, D.C.

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Plus or Minus 1° Centigrade . . .

That's the temperature uniformity a user reports he has attained in a Hevi-Duty Tube Furnace engaged in silicon wafer production

Temperature uniformity is tough to achieve. Yet, a Hevi-Duty user reports that his 22-inch-long, 2-inch I. D. furnace has only a ±1°C. temperature variance over 10 inches of furnace length at 1275°C.

Temperature uniformity — so important to producers of semi-conductor products — has been important to Hevi-Duty for years. Attention to this factor has paid off. It has made Hevi-Duty the respected furnace name in the semiconductor industry.

Whenever critical temperatures must be met, you'll find Hevi-Duty equipment. For years, the largest semiconductor manufacturers have used Hevi-Duty furnaces and ovens for zone refining, crystal growth, alloying, lead attachment, surface treatment and encapsulating.

Your Hevi-Duty sales engineer will show you how these proven furnaces and ovens can meet your needs, or write for Bulletin 459.

HEVI-DUTY

Electric and Fuel-Fired Industrial Furnaces and Ovens

B P C

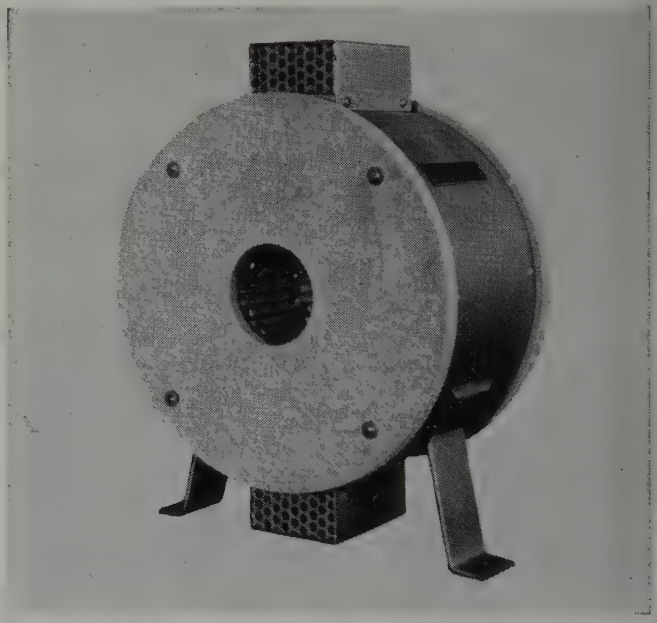
A Division of Basic Products Corporation

Hevi-Duty Electric Company, Milwaukee 1, Wis.

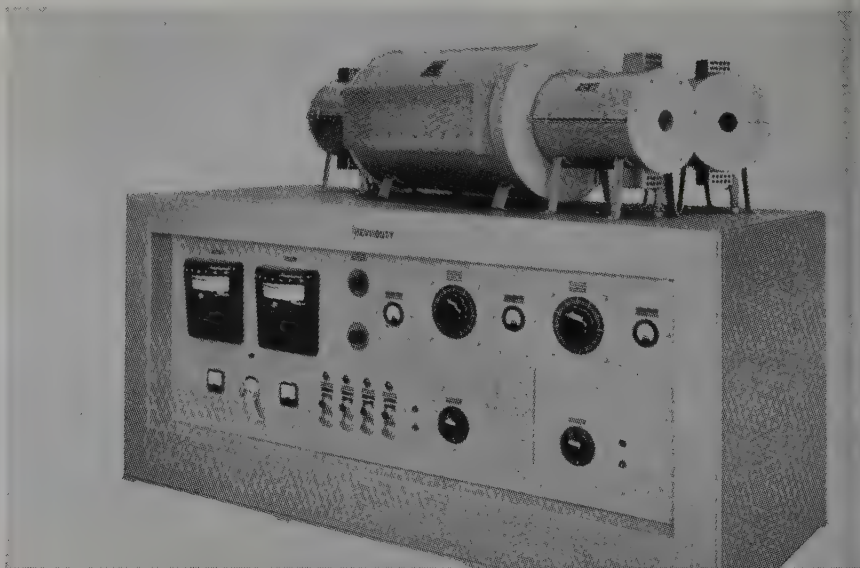
Circle No. 23 on Reader Service Card

This special Hevi-Duty furnace assembly is designed for alloying transistors. An automatic saturable reactor temperature control system is built into the base. A preheat furnace operates at temperatures to 2200°F while the two-zone high-heat furnace operates at temperaturs to 2600°F.

Zone refining is accomplished in this special tube furnace with a 3-inch I. D., 4-inch-long heating chamber. The furnace operates at temperatures to 2200°F and can be easily adapted to move along a track for either crystal growth or zone refining.



These two furnaces are being used successfully for the diffusion of silicon wafers. Boats are preheated in the small furnace to the right and then placed in the three-zone high-heat furnace. The cabinet contains saturable reactor controls that automatically maintain correct temperatures in each furnace.



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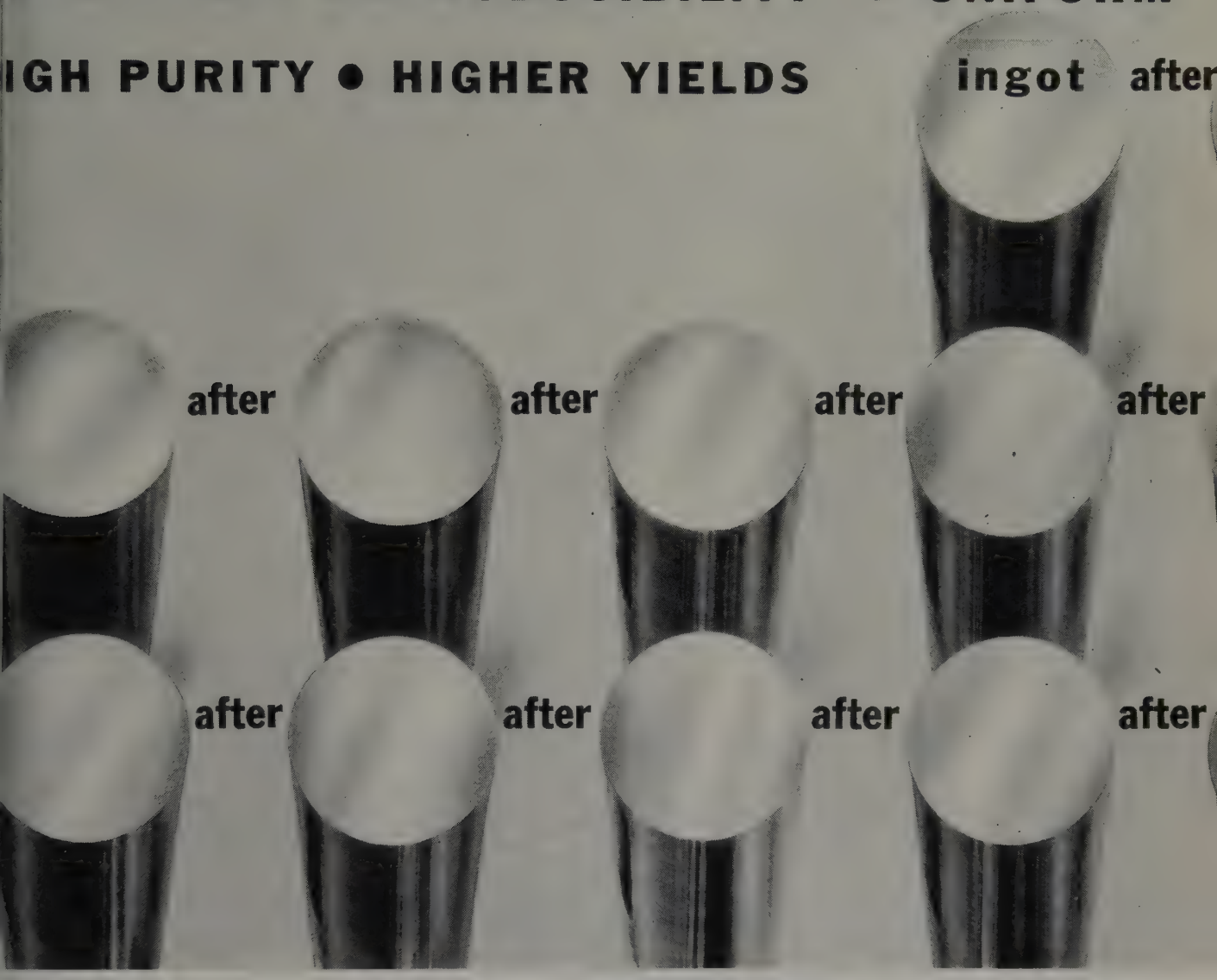

...*ngle crystal* MONSANTO SILICON — float-zone-...fined with parameters *precision-tailored* to customers' ...ecifications—assures these advantages:

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- Excellent crystal structure—*no slippage or lineage*
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...ow your own? Find out how Monsanto micropure *poly-...stalline* silicon can help boost your ingot yield. Boron ...ntent guaranteed less than 0.25 parts per billion ...pically less than 0.15 ppb).

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MONSANTO SILICON is being produced in this modern multimillion-dollar plant—backed by a 60-year tradition of "tailoring" materials to critical specifications.

Here, too—and at other R&D facilities—Monsanto Scientists and Technologists are developing promising new semiconductor materials and processing advances—including new poly and single crystal intermetallics. We cordially invite your inquiries.

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Please send me: ☐ Monsanto mono- and polycrystalline silicon specifications. ☐ Information about new intermetallics.

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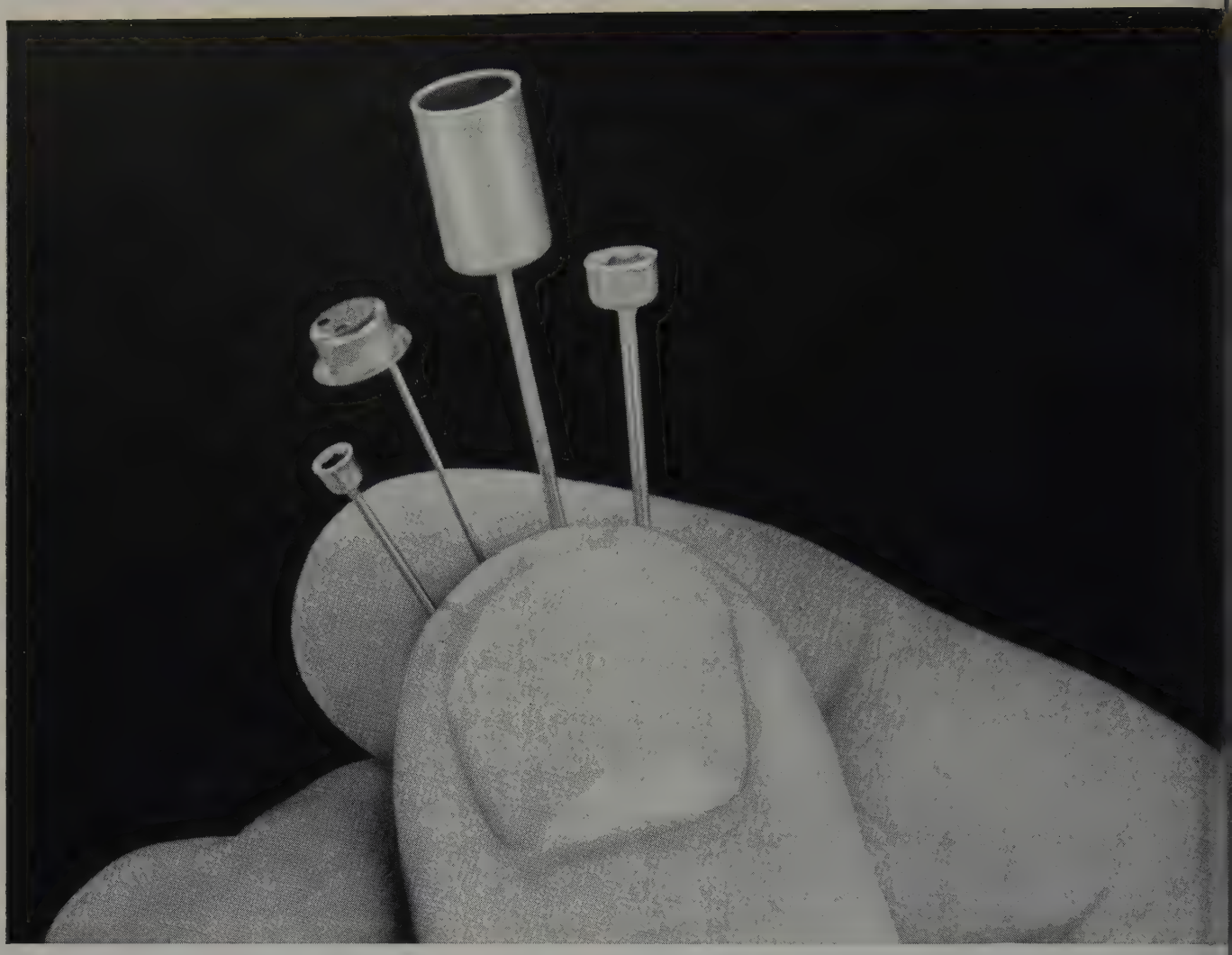

Now put your fingers on top-quality welded assemblies for semiconductors...by the millions!

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AT GRACE ELECTRONICS the pledge of high quality Silicon meeting your specifications is not a promise without meaning. The reason: Perfection is *standard* at Grace!

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Grace Silicon is available in all grades and forms. Bulk: Grades I, II and III; P and N type. Grace Float Zone and Czochralski monocrystals from 0.1 to 1000 ohm-cm. Polycrystalline rods. Monocrystalline slices. Write today for details.

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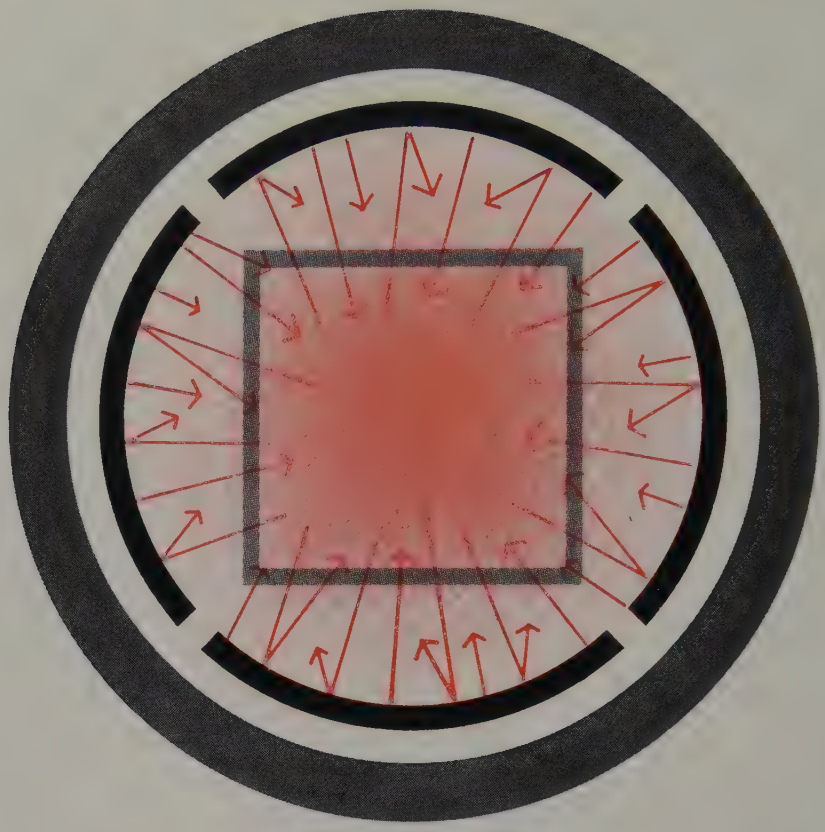

HIGHER TEMPERATURE HIGH VACUUM OVEN

New and now available to industry—a low cost, high temperature, high vacuum bake oven. Tri Metal's 0-8 oven operates at 800°C while maintaining pressures as low as 1 x 10^{-6} mm Hg.

The 0-8 achieves temperature uniformity of 3° at 0 to 800°C and is the low cost oven that functions perfectly at temperatures above 250°C and pressures on the 6th scale without custom modification.

Tri Metal's new oven not only saves you money at purchase time, it is also extremely economical to operate and easy to maintain.

No water-cooling of the door is required. Accepts bench or dry box mounting.

Tri Metal Works has been engaged in the custom fabrication of high vacuum components and equipment for leading manufacturers and users since 1946. You are invited to see a demonstration of 0-8 in our plant laboratory. Call or write for appointment.

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Low-Cost, Neoprene "O" ring gaskets guaranteed one year.

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500°C in 23 minutes.

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1/C Thermocouple INSIDE the work zone.

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1 x 10^{-6} Torr* (mm Hg) @ 500°C.

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All surfaces cool to the touch.

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*terminology recommended by Standards Committee of American Vacuum Society

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SEMIMETALS, INC.

172 Spruce Street • Westbury, L. I., N.Y. • EDgewood 3-8400

Circle No. 20 on Reader Service Card

Prove to yourself that Alpha base tabs eliminate semiconductor device failures caused by faulty ohmic contact.

See what happens when you place a lighted match beneath a piece of Alpha coated strip. Notice that, even when liquid, the strip's Continuous Conductive Coating* clings to the base metal in a smooth, uniform layer.

Next, using a bit of sandpaper, try removing the solder coating... Observe that coating and base have not separated during the heating operation. The reason? Alpha's Continuous Conductive Coating process insures a *permanent, metallurgical bond* between the solder and base metal!

As a result, for the first time, it is possible to produce coated strip with the following unique advantages:

1. **Coatings ranging in thickness** from .0005" to .004" can be applied.
2. **These coatings can be added** to the base metal's *entire* surface or just a *part* of it. This latter feature frees one or both ends of the tab for welding to the base without the danger of solder splatter!
3. **The base metal** can be supplied in all tempers.
4. **A large variety of alloys** containing n or p type dop can be applied to a wide range of base materials.

Another advantage of this process is that it produc uniform coating thickness. This is an important featu safeguarding alignment of the dice on the base tabs, electrical resistance and reliable mechanical stability a result, you enjoy better in-process control of base soldering; *positive ohmic contact is assured!*

See if you don't agree that Alpha coated strip can your semiconductor device costs. Make the match Write for samples of Alpha coated strip. We'll also s you free Alpha Technical Bulletin No. 107, "Alloy Co Metals." Act now!

*Pat. appl

WHEN DEPENDABILITY COUNTS!

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Other Alpha products: High purity dot materials — spheres, discs, cylinders, cubes, drops, ers, rings and special shapes fabricated to your requirements.

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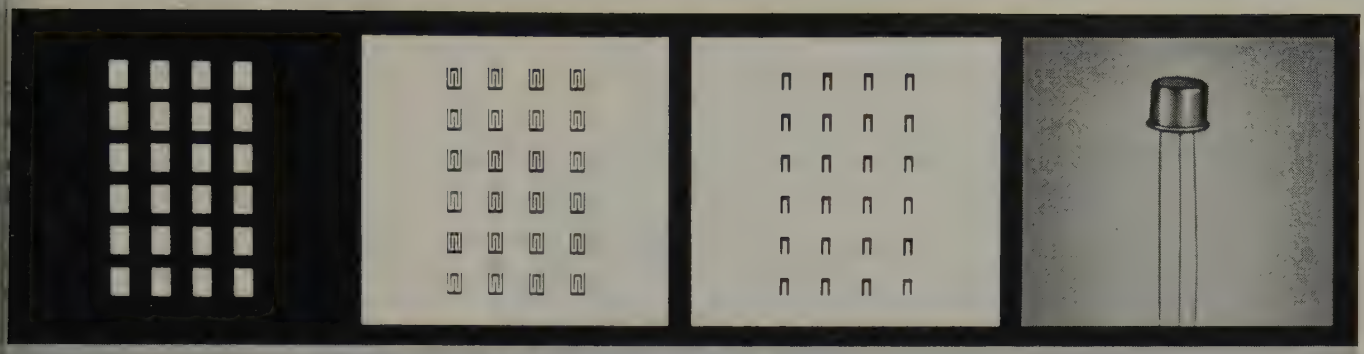

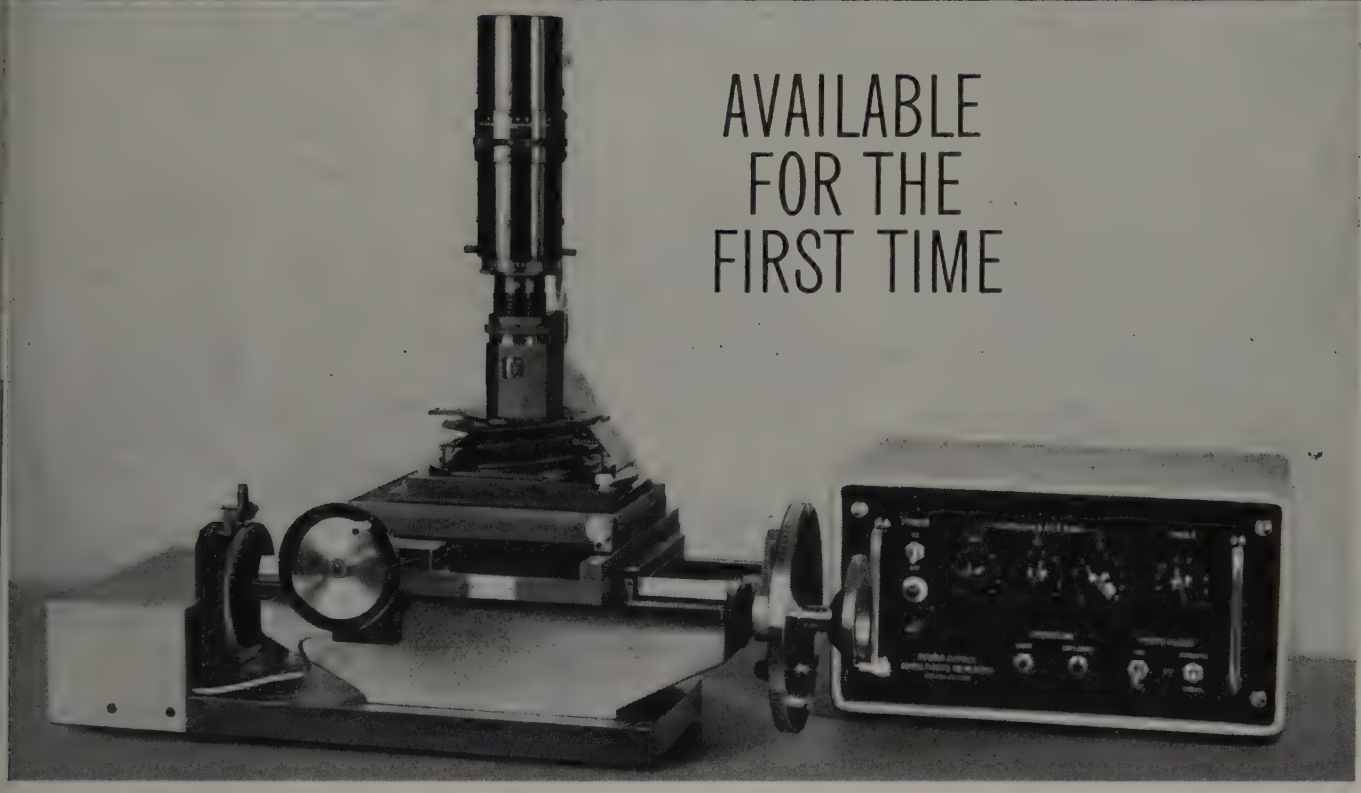

MANN PRECISION PHOTOREPEATER FOR **STEP AND REPEAT** PRODUCTION OF TRANSISTOR PHOTO-MASKS

For more than a year, the transistor industry has looked to the David W. Mann organization for photo-masks meeting the highest precision standards of dimensional accuracy. Now, the same equipment that Mann developed for photo-mask production is offered to transistor manufacturers on either an outright purchase or lease basis.

The advantages: *Cost and time savings when new masks are needed; Convenience in experimenting with new types of masks; Complete proprietary security.* Consisting of a two-coordinate comparator coupled with a control unit, the Photographic Exposure Repeater provides extremely exact positioning of patterns to an accuracy of 1 micron (.00004 inches), exact focusing and precise ratio of reductions.

A programming mechanism, capable of performing various combinations of *step and repeat* operations, makes exposures automatically. Or, the equipment can be used manually to make specially spaced exposures.

A three-pin plate positioning mount is furnished, so that an aligned series of plates may be accurately positioned and exposed. A mask use fixture of identical configuration makes it possible to insert a series of photo-masks and produce precisely aligned successive exposures of the semiconductor material.

The Exposure Repeater is available in three basic models — Industrial, Research and Manual — one of which will meet your particular requirements at minimum cost. Write or phone for complete details.

DAVID W. MANN COMPANY

A DIVISION OF GEOPHYSICS CORPORATION OF AMERICA
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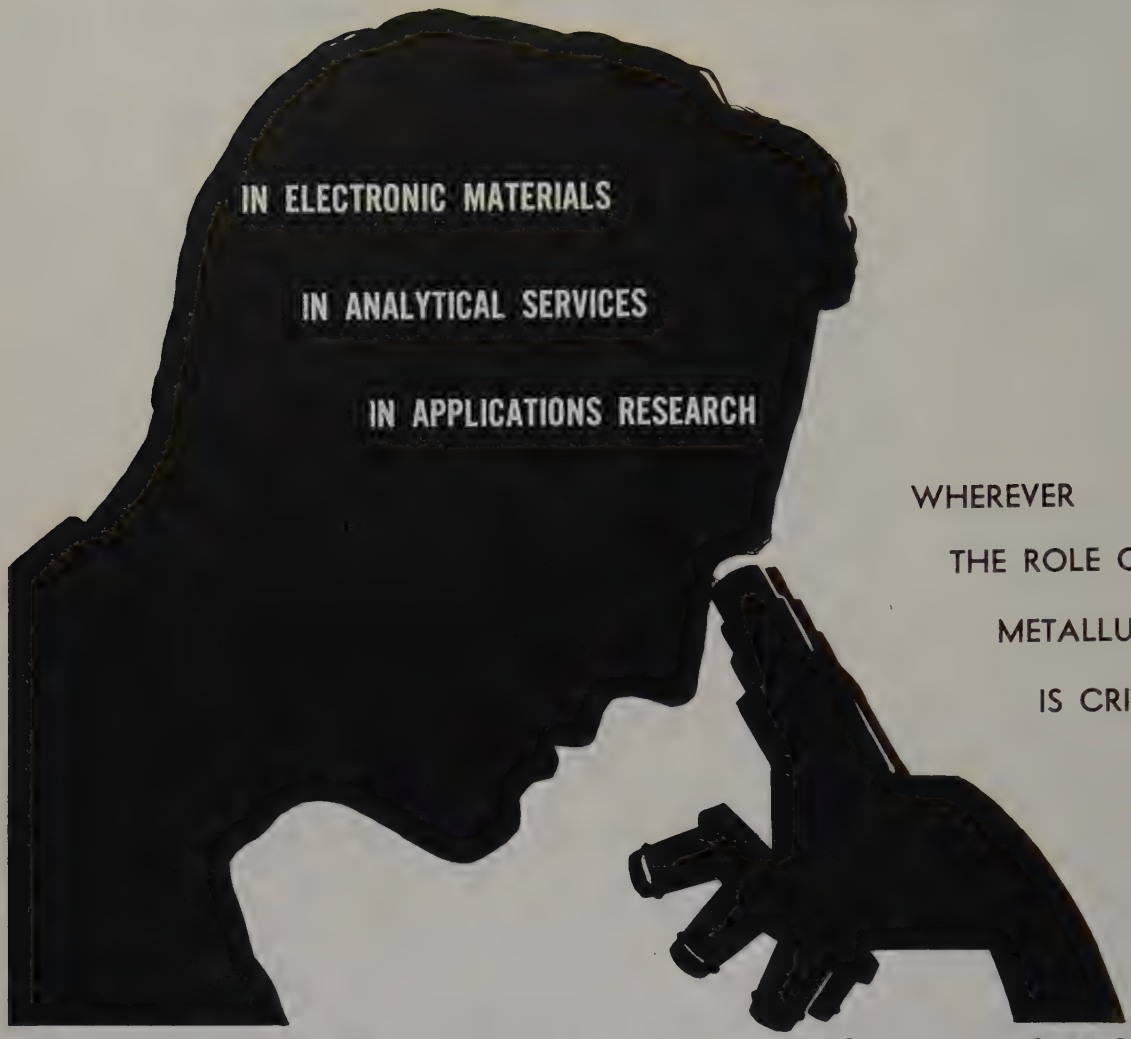

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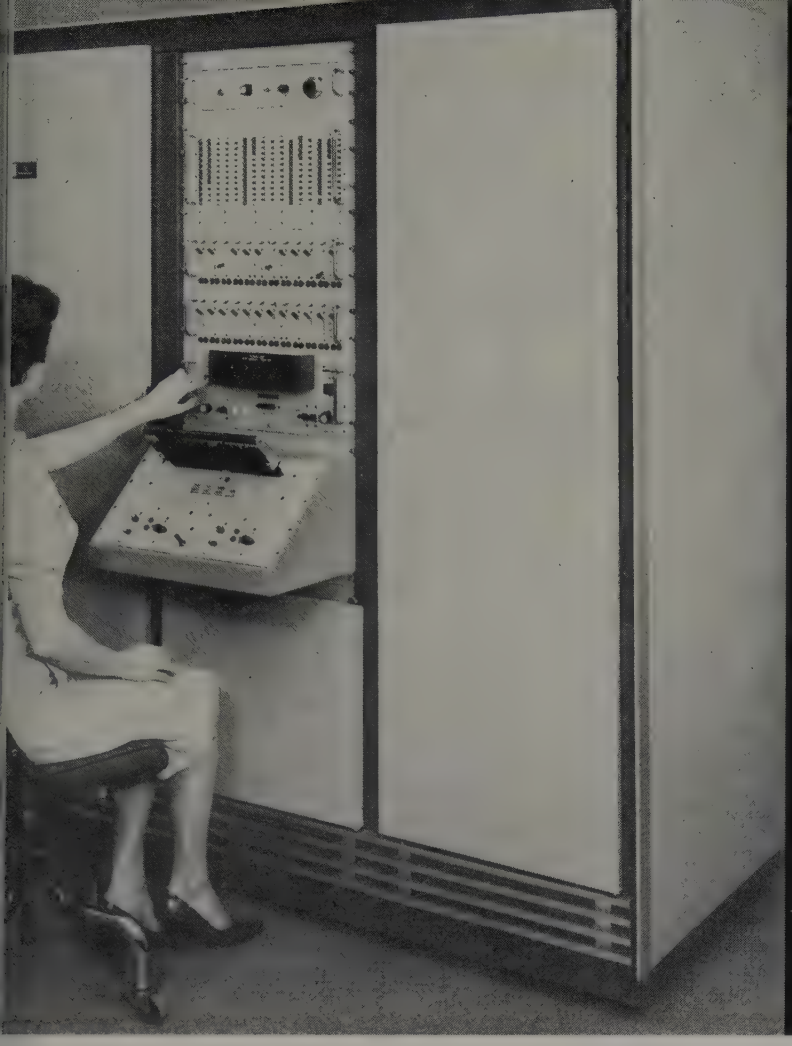
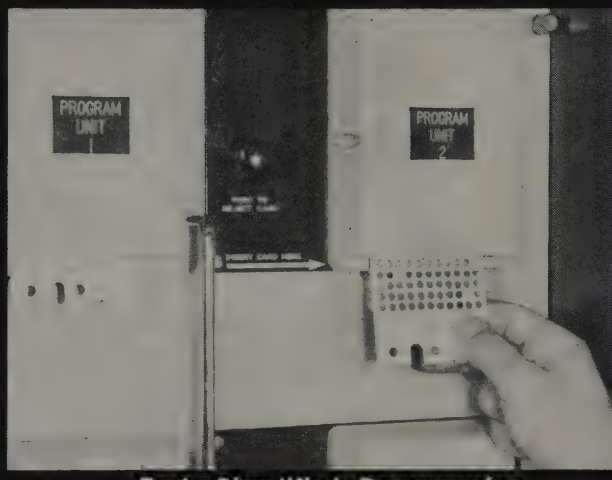


new from TI

tact

TRANSISTOR AND COMPONENT TESTER



Fast, Simplified Programming With Punched Cards

MAXIMUM VERSATILITY *PLUS* ECONOMY

tact BUILDING-BLOCK DESIGN GIVES YOU BOTH!

TACT is a universally applicable transistor and component tester that will meet both present and future requirements without undue investment. It is a sequentially controlled system which advances through as many as 24 test parameters, applying pre-programmed test limits and visually reading out and/or recording measured results. Time-proved test circuitry is combined with punched-card programming to produce a highly accurate system of high sequential testing speeds.

TACT systems won't become obsolete—can be expanded to accommodate future tests or extended to testing printed circuit boards, modular circuits, etc.

High Testing Accuracy results from reduction of readout and signal cable leakage and interference. Test circuitry cabling has been reduced to approximately one-tenth of other designs offering similar testing capabilities.

Repeatability of Testing is maximized by punched-card programming and remote control of common test circuitry. Program cards can be retained and used indefinitely, assuring high repeatability and a permanent record of test conditions.

Nontechnical Personnel can operate TACT systems with minimum training. Reprogramming can be accomplished in minutes without circuit board or plug-in unit changes.

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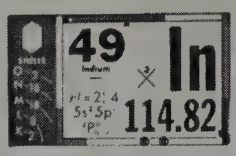

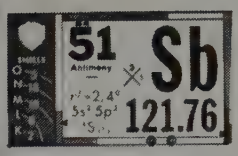

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When you specify

COMINCO INDIUM ANTIMONIDE

you can get:

— Electron Mobilities up to 700,000 cm^2/volt — sec (78°K)
— Net Carrier Concentrations from 10^{14} to 10^{18} cm^{-3} (78°K)
— Single and Polycrystalline forms doped to your specifications
— Shapes as versatile as your needs — circles — rings — rectangles — bars — made to precise tolerances

plus

SPECIAL PACKAGING

To prevent in-transit damage to electronic properties, ingots of **Cominco Indium Antimonide** are sealed in polyethylene and shipped in shock-proof containers. Fabricated shapes are suspended in an inert liquid.

plus

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ELECTRONIC MATERIALS DEPARTMENT
Spokane, Washington
933 W. Third Ave. Phone: RIverside 7-7103 TWX: SP311

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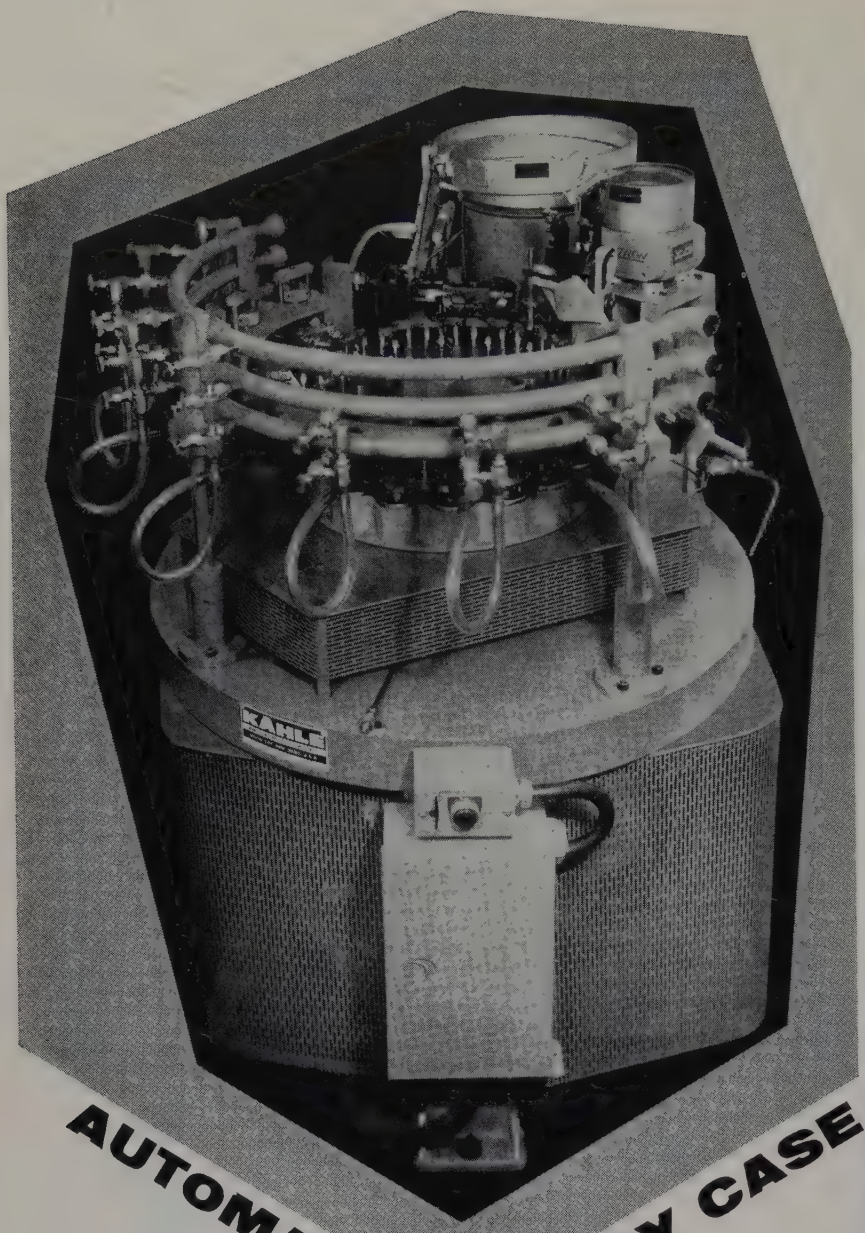
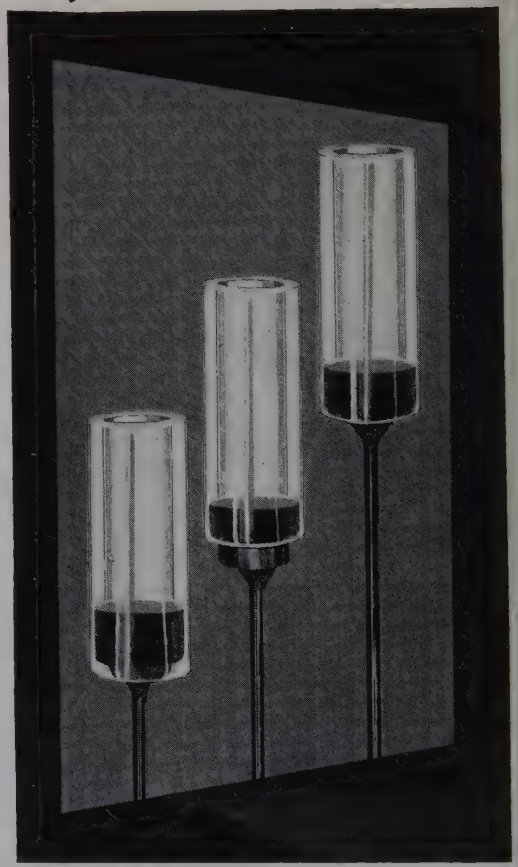
SEMICONDUCTOR DIODE SOURCE BOOK

WATCH FOR ANNOUNCEMENT



SEMICONDUCTOR PRODUCTION MACHINES

AUTOMATIC DIODE BODY CASE MACHINE



A production machine
for a critical production operation
in the manufacture of CRYSTAL DIODES

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Editorial . . .

Infrared Semiconductor Emitters

At the recent Second International Conference on Quantum Electronics (Berkeley, Calif., April 1961) the scarcity of coherent and incoherent sources in the infrared range was emphasized. Such scarcity is caused mostly by the experimental difficulties involved; which may be traced to the unavailability of suitable detectors and to the low temperatures needed.

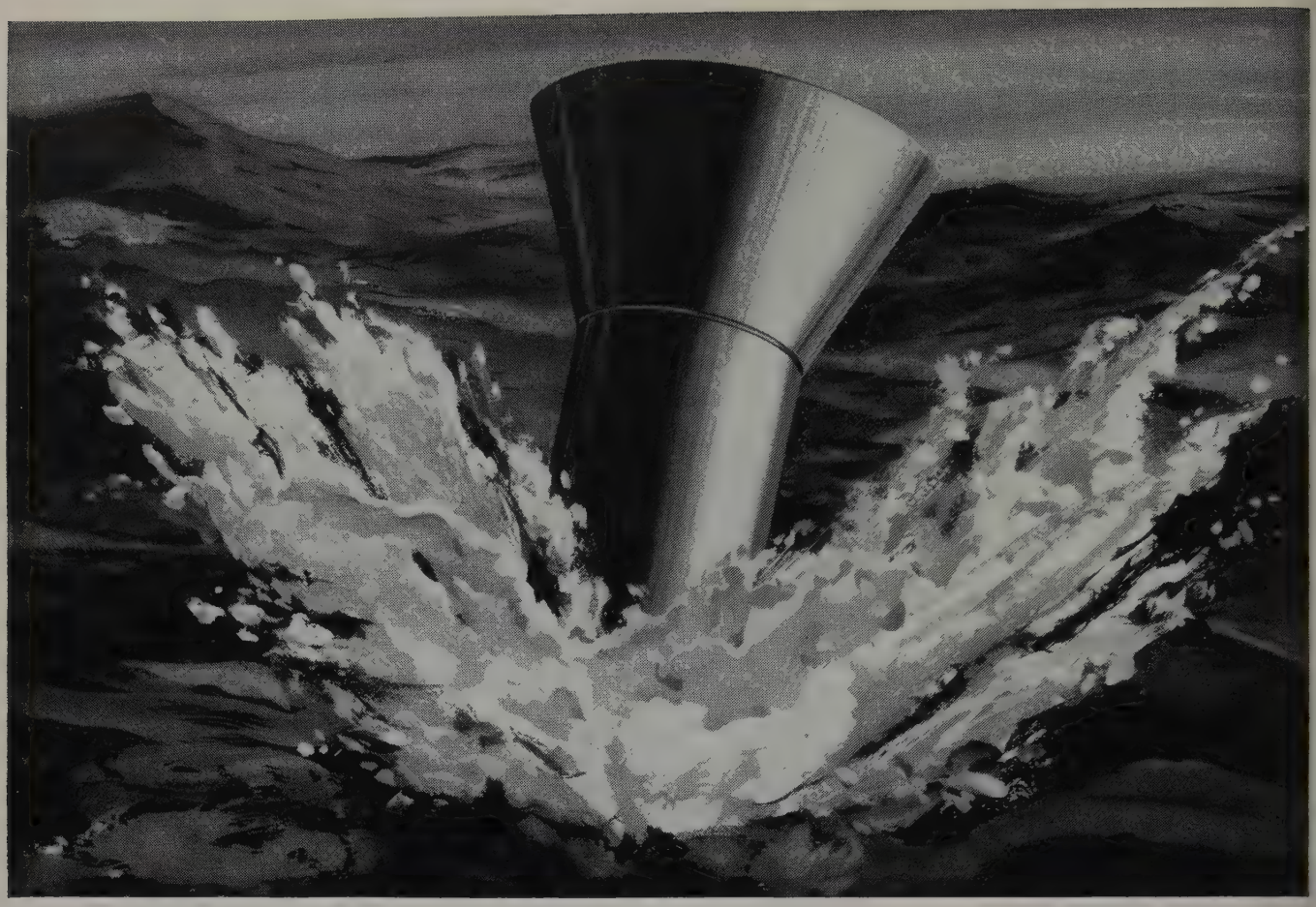
Semiconductors are well suited as detectors and as emitters in the infrared. The wavelengths of absorption and of emission are expressed in terms of the energy difference (V in electron-volt) of the allowed transitions as follows: $\lambda = 1.232/V$ microns. Hence transitions between levels of 1.2 eV or less provide wavelengths of one micron or more. Such transitions may be obtained in a number of semiconductors for levels of the conduction band; levels inside the forbidden gap, and levels of the valence band. In general, however, operation at very low temperature is required, because the current of thermal dissociation is proportional to $T^3\exp(-qV_g/kT)$ where V_g corresponds to the energy gap. In recent years lead selenide and lead sulphide have been utilized successfully as I-R detectors in the 0.7-4.5 μ range.

The family of II-VI semiconductor compounds presents considerable interest for use as detectors and as emitters in the I-R range. In order of increasing wavelength they may be listed approximately as follows: ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, HgS, HgSe, and HgTe. However, mercury selenide and mercury telluride have not yet been studied completely and their emission bands are not known.

Zinc sulphide and cadmium sulphide possess emission bands respectively in the blue-green and in the near infrared ranges corresponding to transitions from the conduction band levels to trap levels located inside the gap. They also present emission and absorption bands in the 1-2 μ range corresponding to transitions from said trap levels to the levels of the valence band.

The addition of cobalt quenches the visible emissions and adds another emission band at about 3 μ. Mercury sulphide has emission bands in the vicinity of 2.3 μ at room temperature and at somewhat longer wavelength at lower temperature. Cadmium telluride is very attractive because of the simplicity of preparation as single crystals and because of the amount of information already acquired about its level structure. Cadmium telluride crystals are formed in an atmosphere of argon and are subjected to a diffusion process in an atmosphere of cadmium vapors at 950° C to form p- and n-type regions. Five distinct emission bands are found in the range 0.88 μ to 2.5 μ; the location of these bands can be controlled to a certain extent by the addition of dopants such as copper chloride.

The advancement of the art in the infrared range has been very significant and semiconductors are expected to play a very important role in this field.



HOW THE OCEAN GREW "EARS" TO PINPOINT MISSILE SHOTS

A quarter of the world away from its launching pad an experimental missile nose cone enters its ocean target area.

How close has it come to the desired impact point?

Where actually did the nose cone fall?

To answer these questions quickly and accurately, Bell Laboratories developed a special system of deep-sea hydrophones—the Missile Impact Locating System (MILS) manufactured by Western Electric and installed by the U. S. Navy with technical assistance from Western Electric in both the Atlantic and Pacific Missile ranges. MILS involves two types of networks.

- One is a long-distance network which utilizes the ocean's deep sound channel. It monitors millions of square miles of ocean. The impacting nose cone releases a small bomb which sinks and explodes at an optimum depth for the transmission of underwater sounds. Vibrations from the explosion are picked up by hydrophones stationed at the optimum depth and carried by cables to shore stations. Time differences in arrivals between these vibrations at different hydrophones are measured and used to compute location of the impact.
- The other is a "bull's-eye" network that monitors a restricted target area with extraordinary precision. This network is so sensitive it does not require the energetic explosion of a bomb but can detect the mere splash of a nose cone striking the ocean's surface—and precisely fix its location.

The universe of sound—above the earth, below the ocean—is one of the worlds of science constantly being explored by Bell Laboratories. The Missile Impact Locating System reflects the same kind of informed ingenuity which constantly reveals new ways to improve the range of Bell System services.

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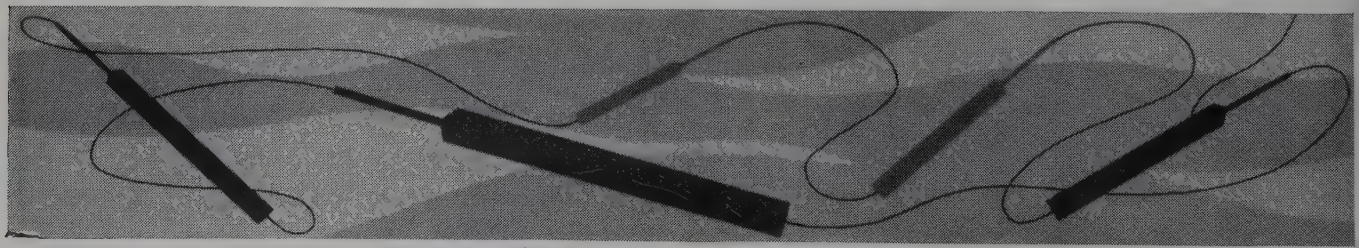

Circle No. 27 on Reader Service Card

A New Concept In Transistor Converters

L. PLUS* R. A. SANTILLI*

This article describes the characteristics of a new double-emitter drift-field transistor, the 3746, and discusses its use in transistorized broadcast-band receivers. This transistor, which functions simultaneously as a mixer and oscillator, makes it possible to obtain an improved a-g-c characteristic. It is particularly advantageous when an r-f stage is not used. Several typical circuits using the 3476 are shown and evaluated.

AN IMPROVED A-G-C CHARACTERISTIC in transistorized broadcast-band receivers is made possible through the use of a new drift-field transistor designed to function simultaneously as a mixer and oscillator. The device may be used in any transistorized broadcast-band receiver, but it is particularly advantageous when an r-f stage is not used. It is the purpose of this article to describe the characteristics of the new transistor, and to show several typical circuits in which it may be used.

Device Description

In order for a device to perform two functions simultaneously, a multi-junction structure is necessary. The new RCA-3746 drift-field transistor consists of the following elements: two alloyed p-type emitters, an n-type base, and one alloyed p-type collector. The two emitters are processed so that they can function independently of each other. The emitters contain gallium, which results in a high hole-injection efficiency.

The base is a diffused n-type region which has a graded impurity concentration. The impurity distribution is a maximum at the emitter junctions, and decreases to a constant value near the collector junction. This type of impurity distribution makes it possible to achieve better frequency response, higher gain, and lower feedback capacitance. The collector periphery encompasses the two emitters and thus assures the collection of carriers injected from either emitter.

Figure 1 shows a cutaway drawing of a mounted assembly of the double emitter unit. A TO-1 type outline is used for encasing the unit.

Circuit Considerations

The use of the double-emitter drift-field transistor in mixer-oscillator circuits provides several advantages over a conventional autodyne converter. The first and most important characteristic is good a-g-c (automatic gain control). Although a-g-c may be applied to an autodyne converter in a broadcast-band portable or an automobile receiver, the amount of control obtainable is limited by the oscillator portion of the circuit. Once the end-of-battery-life voltage or low supply voltage is specified, the maximum a-g-c obtainable is fixed. In practical cases where good performance is expected down to 50 or 60 percent of nominal supply, this a-g-c rarely exceeds 10 db.

Because the double-emitter drift-field transistor can perform the functions of oscillator and mixer independently, a-g-c can be applied to the mixer portion of the circuit without affecting the oscillator performance. In addition, the mixer operating conditions can be optimized with respect to circuit performance without regard for the oscillator quiescent operating conditions.

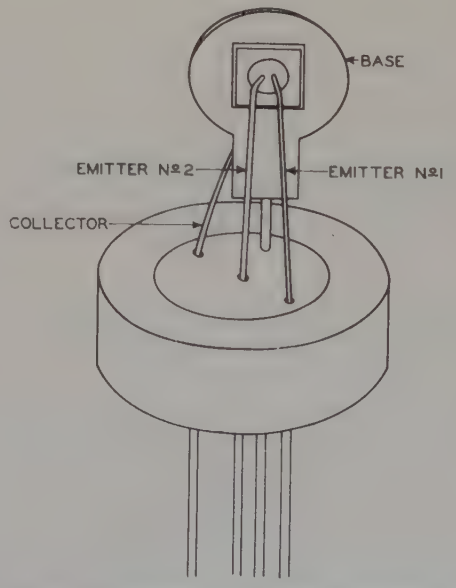

Fig. 1—Cutaway drawing of double-emitter drift-field transistor.

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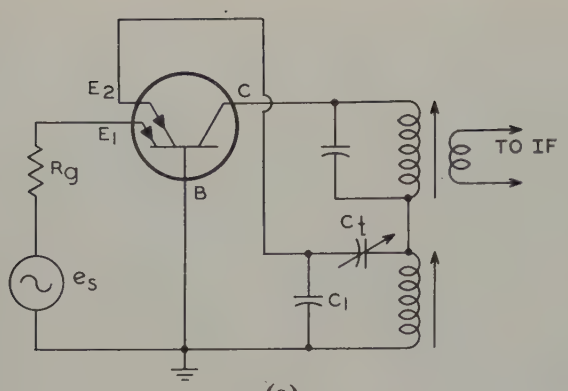
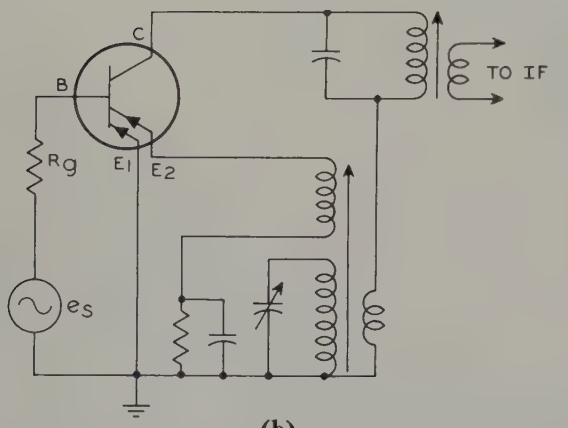


(a)



(b)

Fig. 2—(a) Basic mixer-oscillator circuit, common base. (b) Basic mixer-oscillator circuit, common emitter.

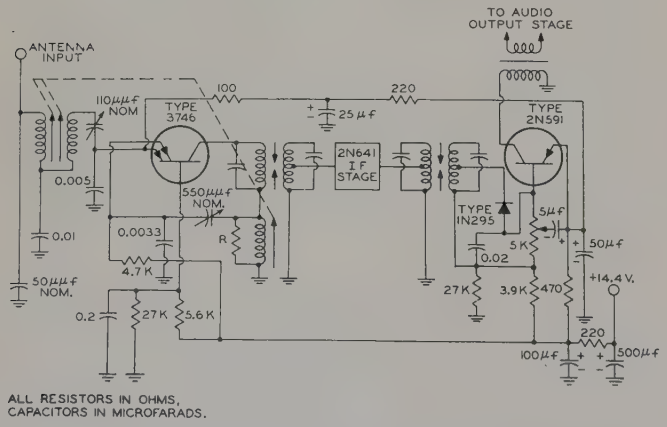


Fig. 3—Typical oscillator-mixer stage; audio amplifier is used as the a-g-c amplifier and a-g-c is taken from the secondary of the last double-tuned i-f transformer.

Fig. 2(a) shows a basic mixer-oscillator circuit using the new transistor. Isolation for a-g-c is provided by the use of emitter No. 1 as the signal emitter and emitter No. 2 as the oscillator emitter. Both oscillator and mixer circuits are operated in the common-base configuration. In the oscillator circuit, feedback is applied from collector to emitter No. 2 by means of the capacitance-divider network C_t and C_1. Signal is applied to emitter No. 1, and the i-f output is taken from the single-tuned i-f transformer in the collector circuit. A-g-c is obtained by a decrease of the quiescent current in emitter No. I.

The amount of a-g-c which can be obtained from the circuit is a function of the external isolation of the signal on emitter No. 1 from the oscillator emitter (emitter No. 2). External coupling of the signal to emitter No. 2 causes the oscillator portion of the circuit to operate as a conventional autodyne converter and reduces the a-g-c capabilities of the device.

The double-emitter transistor may also be operated in the common-emitter configuration for the signal frequency and the common-base configuration for the oscillator, as shown in Fig. 2(b). The a-g-c obtainable by this technique is considerably less than that achieved with the circuit of Fig. 2(a) because of the coupling of signal to emitter No. 2. The maximum a-g-c depends on the degree to which emitter No. 2 can be degenerated with respect to signal, and on whether the quiescent operating conditions at emitter No. 2 are optimum for mixing. Practical a-g-c figures for the circuits of Figs. 2(a) and 2(b) are 54 db and 20 db, respectively. In either case, the application of a-g-c by a decrease of the current in emitter No. 1 does not appreciably affect the operating point of the oscillator circuit. Although inductive tuning is shown in Fig. 2(a) and capacitive tuning in Fig. 2(b), the common-base and the common-emitter configuration and the a-g-c techniques described below are applicable to either tuning method.

A-G-C Techniques

A-G-C may be applied to either the base or the emitter No. 1 of the mixer-oscillator stage. Fig. 3 shows the r-f and driver stages of a developmental inductance-tuned receiver which uses the double-emitter transistor as the mixer-oscillator, an RCA 2N641 drift-field transistor as an i-f amplifier, and an RCA-2N591 conventional alloy transistor as a driver. The oscillator portion of the first stage operates at an emitter current of 0.45 milliampere and develops approximately 150 millivolts of oscillator voltage at emitter No. 2. This oscillator voltage has a tendency to increase with decreasing frequency as a result of the increasing oscillator load impedance. A resistor R is shunted across the oscillator coil to maintain the oscillator voltage relatively constant. (The mixer gain of the stage is relatively constant for injecton-voltage variation between 100 and 200 millivolts.) The mixer portion operates at an emitter current of one milliampere and provides a conversion gain of 28 db when operating into a 400,000 ohm i-f load (262 kilocycles). The gain of the mixer portion is controlled by referring emitter No. 1 to a point which is at the proper potential with respect to the base and can be made to go positive with increasing r-f signal level. In this circuit, the detector is direct-coupled to the audio driver. The detected signal produces a negative voltage at the base of the driver transistor which increases the current in that stage. If the mixer emitter is connected to the audio-driver emitter, the increasing audio-driver current applies

a negative voltage (relative to its no-signal potential) to the mixer emitter, which decreases its current.

This technique may also be applied to the i-f stage. Conventional a-g-c (except for increasing i-f current) is applied to the i-f transistor, and the mixer emitter is returned to the i-f emitter. A disadvantage of this system is that the i-f stage must be designed for the highest current to be used and then operated at a lower current at sensitivity. For a receiver using a minimum number of stages, this requirement results in a loss of sensitivity.

In actual operation, the current in the audio-driver emitter resistor changes from 2.5 milliamperes (one milliampere of mixer current plus one-and-a-half milliamperes of driver current) to approximately 4.0 milliamperes with increasing input r-f signal. Under these conditions, approximately 54 db of a-g-c is obtained from the mixer stage. This method is particularly useful in broadcast-band portable receivers in which good a-g-c and minimum cost are desirable.

Fig. 4 shows basically the same method, except that the a-g-c is derived from the primary of the last double-tuned i-f transformer through a conventional a-g-c network and applied to the driver transistor. A 2200 ohm isolation resistor is required to prevent the audio signal from shorting to B+ through the a-g-c capacitor. This method is useful in automobile receivers in which primary a-g-c is desirable.

Fig. 5 shows a circuit diagram in which a-g-c is applied to the base of the double-emitter mixer circuit. The a-g-c is derived from the primary of the last i-f transformer and applied through a separate a-g-c diode to the a-g-c network. (The audio detector diode could also be used here.) The a-g-c voltage developed is applied directly to the base of the mixer-oscillator unit. The emitter of the oscillator section must be referenced to a point which follows the base potential, such as the a-g-c line, so that it will not be cut off. However, if emitter No. 2 is placed on the agc line, the agc diode also must carry the current in emitter No. 2; the result is delayed and ineffective a-g-c. This effect is even more severe if the a-g-c is derived from the audio detector because this increased current reduces the audio detector efficiency at sensitivity. Consequently, emitter No. 2 is referenced to a point between the a-g-c line and B+ so that approximately half of the current in emitter No. 2 flows directly to B+ and the remainder through the diode. The connection to B+ causes the current in emitter No. 2 to decrease with a-g-c, whereas connecting it to the a-g-c line causes a slight increase in this current with a-g-c. A point should be found between the a-g-c line and B+ where the emitter No. 2 current remains constant with a-g-c, as in the circuit of Fig. 5. Component values for the establishment of this reference point are not critical. (A 262-kilocycle trap is located in the bias circuit to prevent loading of the a-g-c detector.) Amplified a-g-c is then taken from emitter No. 1 of the mixer and applied to the base of the i-f amplifier. For dynamic range

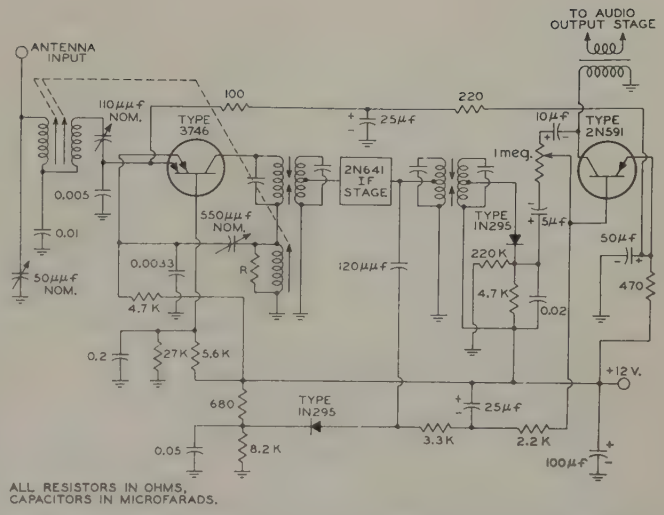


Fig. 4—Typical oscillator-mixer stage; audio amplifier is used as the a-g-c amplifier and a-g-c is taken from the primary of the last double-tuned i-f amplifier through a conventional a-g-c network.

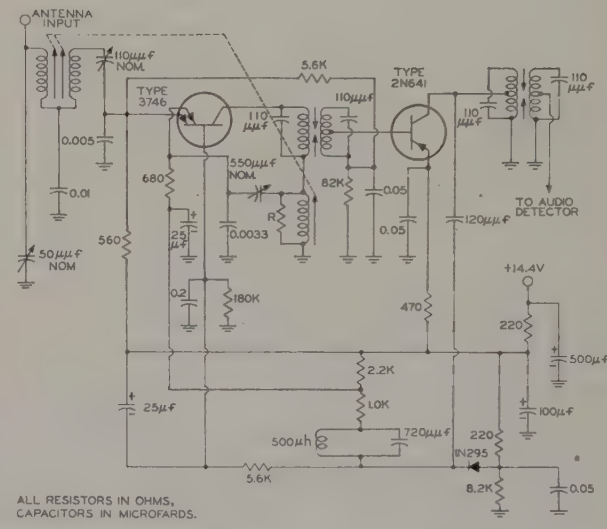


Fig. 5—Typical oscillator-mixer stage with base a-g-c.

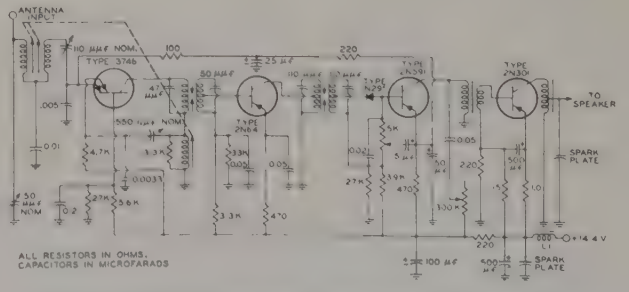


Fig. 6—Four transistor automobile receiver.

considerations, only partial a-g-c can be applied to the i-f stage.

Automobile Receiver Performance

Figure 6 shows the circuit diagram for a developmental four-transistor automobile receiver which dramatically illustrates the potential of this new device. The sensitivity of this four-transistor radio, 18 micro-

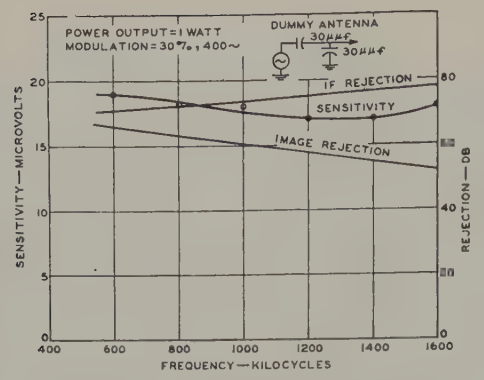


Fig. 7—Sensitivity, image, and i-f rejection versus frequency.

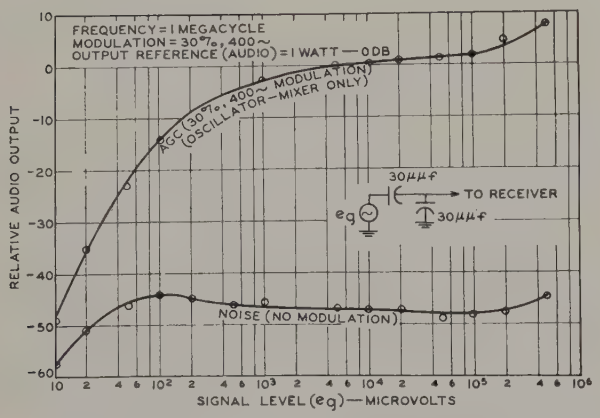


Fig. 8—A-g-c and noise characteristic.

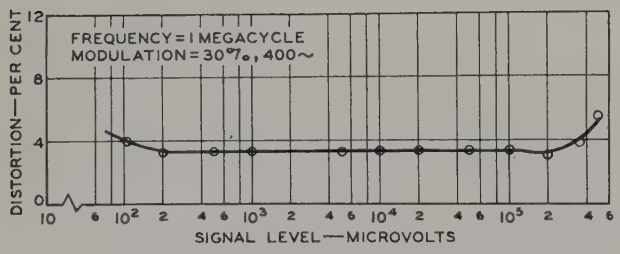


Fig. 9—Distortion versus signal level.

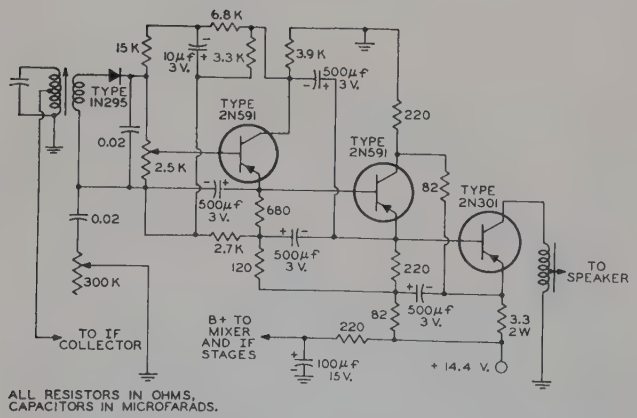


Fig. 10—Direct-coupled, high gain audio circuit.

volts, is admittedly lower than what is considered adequate for high-performance auto receivers, but is representative of present low-cost receivers utilizing no r-f stage. Although this sensitivity can be obtained with four conventional transistors, the a-g-c performance is a virtual impossibility without the use of overload or damping diodes.

The receiver utilizes the double-emitter transistor as a mixer-oscillator, an RCA-2N641 drift-field transistor in the i-f stage, an RCA-2N591 conventional alloy driver, and an RCA-2N301 power output unit. The mixer stage provides a conversion gain of approximately 28 db across the band into a 262 kilocycle i-f transformer. The capacitive whip antenna is coupled to emitter No. 1 through a double-tuned antenna network which provides good image and i-f rejection. A-g-c for the mixer portion is obtained by the secondary audio a-g-c method described in the previous section. The 2N641 in the i-f stage is operated unneutralized at an emitter current of 2.0 milliamperes, and provides an i-f gain of 37 db at 262 kilocycles. Two double-tuned (85 percent of critical coupling) transformers are employed in the i-f stage for good selectivity.

The audio detector is direct-coupled to the base of the 2N591 driver transistor to provide a-g-c to cut off the emitter current of the mixer circuit. The driver stage, which operates at an emitter current of 1.5 milliamperes, provides an audio gain of 43 db. A simple treble-cut circuit is employed in the collector circuit as a tone control. The power-output stage operates at an emitter current of 0.5 ampere into a 35-ohm load to provide an undistorted output (less than 10 percent) of more than 2 watts. The gain of the power-output stage under these conditions is 40 db.

As shown in Fig. 7, the sensitivity of the receiver using a 30-micromicrofarad-series, 30-micromicrofarad-shunt dummy antenna is approximately 18 microvolts across the band. The image and i-f rejections are 68 db and 72 db, respectively, at the low end of the band, and 53 and 78 db at the high end of the band.

Fig. 8 shows the a-g-c and noise characteristics of the receiver at 1 megacycle with a-g-c applied to the mixer unit only. From a 100,000-microvolt reference, the receiver has an a-g-c figure-of-merit of 54 db. (This reference was chosen to evaluate the a-g-c of the mixer unit fairly.) A 20 db signal-to-noise ratio occurs at a signal level of 28 microvolts.

The distortion of the receiver as a function of signal level is shown in Fig. 9. The distortion at an r-f signal of 0.5 volts is 5.6 percent. The increase in distortion at low signal levels is due to noise.

This double-emitter transistor may also be used in receivers utilizing r-f stages. The advantages provided by the device in either portable receivers or automobile receivers include superior a-g-c and the elim-

ination of oscillator blocking due to transient strong-signal conditions. A-g-c can be applied to both the r-f and mixer stages. Partial a-g-c which is normally applied to the single i-f stage may be eliminated to produce maximum dynamic range.

Fig. 10 shows the circuit diagram of a three-stage audio circuit which may be used in conjunction with the front end of the automobile receiver shown in Fig. 6 if the a-g-c circuit of Fig. 5 is used. The circuit employs two RCA-2N591's and an RCA-2N301 power-output transistor, all direct-coupled. All three stages operate in the common-emitter configuration to provide an over-all power gain of 86 db. The sensitivity of the receiver when this audio circuit is used is 13 microvolts across the band. Operating into a 35-ohm load, the power-output unit delivers two watts to the speaker at less than 10 percent distortion.

Portable Receiver Performance

The circuit diagram of a developmental portable broadcast-band receiver is shown in Fig. 11. The converter section of the receiver utilizes a double-emitter mixer oscillator transistor operating in the common-base configuration and a neutralized RCA-2N373 drift-field transistor is used as the i-f amplifier. The mixer circuit provides a conversion power gain of 25 db into a 300,000-ohm, 455-kilocycle i-f load. The i-f stage contributes an additional 37 db of i-f gain. The audio circuit consists of a driver stage and a push-pull output circuit, both of which use RCA-2N408 conventional alloy transistors. The over-all gain of the audio circuit is 73 db, and the output circuit is capable of delivering 150 milliwatts of audio power to the speaker with less than 10 percent distortion. The a-g-c scheme is the same as that shown in Fig. 3 and described previously.

As shown in Fig. 12, this receiver has an average sensitivity of 500 microvolts per meter across the band for 50 milliwatts of audio output. The image and i-f rejections are 28 db and 44 db at the high end of the band, respectively, and 49 db and 35 db at the low end of the band. Fig. 13 shows the a-g-c and noise characteristics of the receiver. From a 400,000 microvolt-per-meter reference, the a-g-c figure-of-merit is 46 db. A signal-to-noise ratio of 20 db occurs at 600 microvolts per meter.

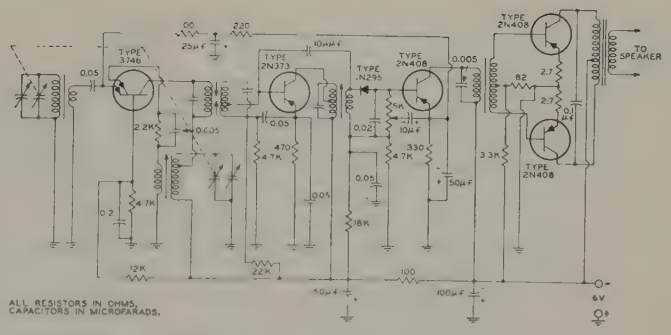


Fig. 11—Four-stage portable receiver.

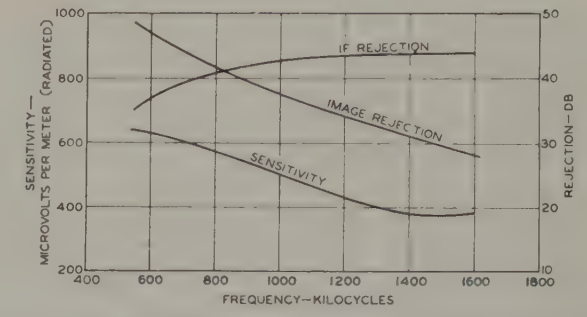


Fig. 12—Sensitivity, image, and i-f rejection versus frequency.

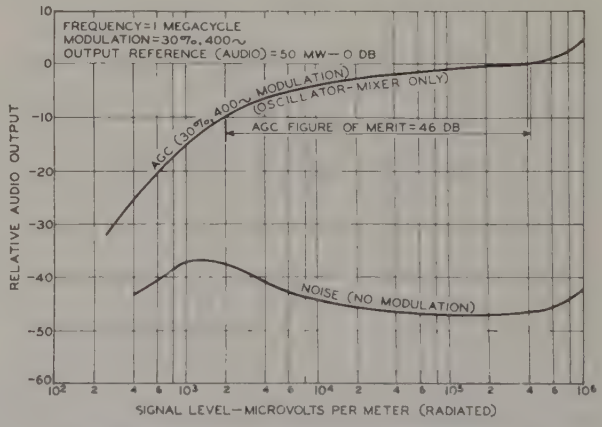


Fig. 13—A-g-c and noise characteristic.

Conclusion

This article has described the device and circuit characteristics of a new double-emitter drift-field transistor the RCA 3746.

Technical feasibility of the device and its application as a combination oscillator-mixer capable of being gain-controlled has now been fully achieved. Among the first significant results of this development will be the design of broadcast receivers having excellent a-g-c performance but using only a frequency converter and single i-f amplifier and eliminating the use of overload or clamping diodes and the problems associated therewith. However, the applications described in this paper are not the only ones for which the device is being considered. Other applications include remote cut-off r-f and i-f amplifiers, reflex amplifiers, and related applications.

Acknowledgment

The authors wish to acknowledge the assistance of Messrs. E. G. Athanassiadis and D. Thorne.

Properties of Hall Effect Multipliers

STEPHEN P. DENKER*

The properties of Hall effect multipliers such as geometry, terminal characteristics, power limitations and temperature variation of output voltage are discussed.

The Hall effect provides a direct means for the multiplication of an input current by an applied magnetic field. In semiconductor materials the phenomenon is quite large and easy to observe. In this article, the properties of Hall effect multipliers such as terminal characteristics, geometry, power limitations and temperature variation of output voltage are discussed. Commercial devices, made from the compound semiconductors indium antimonide and indium arsenide, are currently available.[1]

The origin of the Hall voltage is the deflection of moving charge carriers by a Lorentz force exerted on these carriers by the magnetic field. An electron travels along a curved path until it suffers a collision, after which it begins moving again under the same forces. This process does not continue for long because the electron strikes the surface and remains there as a surface charge. These surface charges establish a transverse electric field in the material until the field is large enough to make the net transverse force identically zero. This transverse electric field gives the Hall voltage (V_H):[2]

$$V_H = \Phi_H \cdot \frac{BI}{t} = \frac{3\pi BI}{8Nqt} \qquad (1)$$

Equation 1 (see *Fig. 1*) is valid for semiconductors in which the mobility of carriers is determined primarily by thermal scattering lattice vibrations.[2] However crystalline structure nearly always introduces anisotropic behavior and associated magnetic effects.[3]

Geometry

To determine the optimum dimensions for a Hall effect device, which will give a large Hall voltage and good frequency response, an electromagnetic boundary value problem must be solved.[4] Geometry of the semiconductor material is extremely important. The sample itself should be as thin as possible. The practical limitation on minimum thickness is merely the sample's mechanical strength. Semiconductors, such as indium antimonide, are very brittle. A sample must be thick enough to permit proper terminal connections. A practical design thickness is about five mils.[5] Even with this thickness the device is not strong enough and must be encapsulated.[6] Encapsulation in a material with high permeability, such as a ferrite material, combines mechanical rigidity with minimum device thickness. This also reduces the effective air gap of the magnetic circuit, which produces the necessary flux density, to its minimum possible value.

Output Voltage and Power Dissipation

Hall effect multipliers are somewhat inefficient and lossy. Heat dissipation in the sample sets the practical upper limit on the Hall output voltage. Because of the loss present, the input current heats the semiconductor sample. The maximum value of current is determined solely by heating considerations and the maximum allowable temperature rise of the Hall effect device.

The heat produced in the semiconductor material is conducted away from the device by its two flat sides which are in contact with the magnetic core in which it is placed. It is useful to note the *rms* dissipated power per unit surface area of the device. This is given by:

$$K = \frac{I^2R}{2wl} \qquad (2)$$

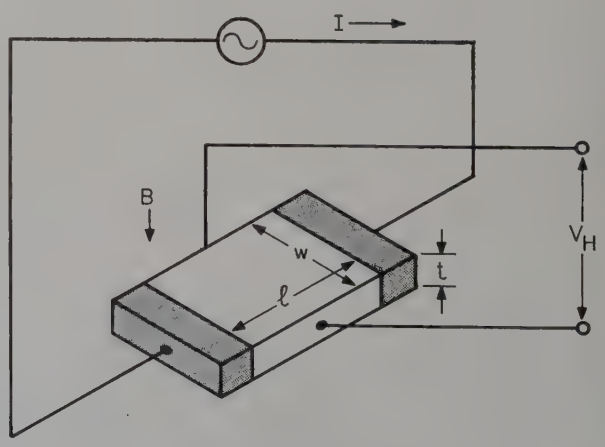


Fig. 1—Hall effect device in a magnetic field (B).

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The resistance of the sample (R) in terms of the sample geometry and resisitivity (ρ) is:

$$R = \frac{\rho l}{wt} \tag{3}$$

Therefore, the input sample current (I) is:

$$I = \sqrt{2w^2 t \rho^{-1} K} \tag{4}$$

With Eq. 1, the Hall output voltage becomes:

$$V_H = \frac{3\pi}{8} \sqrt{\frac{2w^2 B^2 K}{N^2 q^2 \rho t}} \tag{5}$$

It is more worthwhile to characterize the Hall voltage of a semiconductor device in terms of its electron mobility. The electron mobility, (μ), can be related to the resistivity, charge, and carrier concentration as:

$$\mu = \frac{1}{Nq\rho} \tag{6}$$

Therefore, the expression for the Hall output voltage which takes sample heating into account is:

$$V_H = \frac{3\pi}{8} \sqrt{\left(\frac{2w^2 B^2 K}{qt}\right)\left(\frac{\mu}{N}\right)} \tag{7}$$

This equation shows that the ratio of electron mobility to carrier concentration should be as large as possible to achieve maximum Hall output voltage. Also, the input sample current restriction can be lessened if better heat removal is provided. Use of a metallic heat conductor or an oil filled structure around the Hall device can increase the permissable maximum current by two or three times.[7]

Efficiency

We have discussed some of the necessary requirements to be met by the material from which a Hall effect multiplier is constructed. What is the efficiency of power transfer and what parameters are involved in a Hall effect device? If the Hall ouput terminals are connected to a matched load, the power, W_o, delivered to the load is:

$$W_o = \frac{V_H^2}{4R_i} \tag{8}$$

Note that R_i is the output terminal resistance of the multiplier. For the rectangular geometry previously defined in *Fig. 1*, neglecting effects such as magnetoresistance,[8] the internal resistance of the crystal may be approximated as:

$$R_i = s \frac{w}{\sigma l t} \tag{9}$$

where s is a factor of the order of unity which allows for the spreading resistance at the electrodes.[9] The power dissipated in the semiconductor sample by the input current is:

$$W_d = I_o^2 \left(\frac{l}{\sigma w t}\right) \tag{10}$$

Combined with Eq. 1, the power delivered to the load becomes:

$$W_o = \left(\frac{W_d}{4s}\right) (\sigma \Phi_H)^2 \cdot B_o^2 \tag{11}$$

However, $\Phi_H = \frac{3\pi\mu}{8\sigma}$ therefore the power delivered to the load is:

$$W_o = \left(\frac{W_d B_o^2}{4s}\right)\left(\frac{3\pi}{8}\ \mu\right)^2 \tag{12}$$

This equation is strictly true only for small values of the magnetic field so that magnetoresistive effects, which are quadratic with magnetic field, are sufficiently small and can be neglected.

The dissipation of power in a Hall effect multiplier must be by heating. If we are drawing current from the output terminals, it is important to be able to predict the variation of Hall output voltage with temperature. First, let us assume that I_o and B_o are independent of temperature, while the mobility and carrier concentration, as is well known, are not. Suppose we have constant input current and constant load, then Eq. 1 applies. Therefore:

$$V_H = \frac{3\pi}{8} \frac{I_o B_o}{Nqt} \tag{1}$$

$$\frac{dV_H}{dT} = -\frac{3\pi}{8} \frac{I_o B_o}{qt} \cdot \frac{1}{N^2} \frac{dN}{dT} \tag{13}$$

$$\frac{dV_H}{dT} = -\frac{3\pi}{8} \frac{I_o B_o}{Nqt} \cdot \frac{1}{N} \frac{dN}{dT} \tag{14}$$

Which gives the result:

$$\frac{1}{V_H} \frac{dV_H}{dT} = -\frac{1}{N} \cdot \frac{dN}{dT} \tag{15}$$

Thus if we constrain the input current to be constant, then the Hall output voltage will decrease with temperature because the carrier concentration increases with temperature.

Suppose we constrain the input voltage to be constant instead of the input current, then Eq. 1 must be modified. Assuming Ohm's law to be valid then:[10]

$$V_H = \frac{3\pi}{8} (V_o B_o) \left(\frac{w}{l}\right) \mu \tag{16}$$

$$(\mu) \frac{dV_H}{dT} = (\mu)(V_o B_o) \left(\frac{w}{l}\right) \frac{d\mu}{dT} \tag{17}$$

which gives the result:

$$\frac{1}{V_H} \cdot \frac{dV_H}{dT} = \frac{1}{\mu} \cdot \frac{d\mu}{dT} \tag{18}$$

The mobility is proportional to $T^{-3/2}$, characteristic

of lattice scattering. Therefore, its temperature deriviative is negative. Thus as for constant input current, if we have constant input voltage, the Hall output voltage will decrease with temperature. It is reasonable to expect the Hall voltage to always show a negative temperature characteristic regardless of input constraint.

Indium Antimonide and Indium Arsenide

Indium antimonide has a higher electron mobility at room temperature than any other semiconductor material presently available. Because of its higher electron mobility, larger Hall voltages can be produced than with any other material. The mobility of indium antimonide, in the vicinity of room temperature, is very temperature dependent; whereas for the semiconductor indium arsenide the mobility is less temperature sensitive. Devices made of either material are commercially available. For applications in which temperature changes do occur, indium arsenide is the more desirable material.

Both these semiconductors have small energy gaps and low resistivities at room temperature. Their small energy gaps simplify making ohmic contacts to the semiconductor sample. Since indium antimonide has a small energy gap, *p-n* junctions are masked at room temperature by the high intrinsic carrier concentration.[11] Furthermore, their low resistivities make possible Hall effect devices having low impedances.

Semiconductor Hall effect devices have an advantage over most semiconductor devices because they utilize only majority charge carriers and need not involve junctions. Since there are no areas of concentrated electric fields, the surfaces need not be elaborately protected.

Terminal Characteristics

The input terminal impedance of a Hall effect multiplier is a function of magnetic field, input sample current and temperature. Since the input sample current is a term which determines the Hall product voltage (see Eq. 1), the device should be driven with a current source. Hall effect devices employing compound semiconductors such as indium antimonide have nominal terminal impedance of about one ohm. For this reason, a current source drive for a Hall effect multiplier is exceedingly simple to obtain. The output terminal impedance is also about one ohm. This low impedance enables simple connection to the Hall output terminals. In all cases, Hall effect devices made of these materials can be treated as relatively good voltage sources.

Appendix I List of Symbols

B	Magnetic Flux Density	R	Resistance
I	Current	ρ	Resistivity
Φ_H	Hall Coefficient	σ	Conductivity
μ	Electron Mobility	T	Temperature
N	Electron Carrier Density	V_H	Hall Output Voltage
q	Electronic Charge	W	Power

References and Notes

1. Ohio Semiconductors, Inc., Columbus, Ohio; Siemens and Halske AG Munich, Germany and Westinghouse Corp., Pittsburgh, Pennsylvania. Indium antimonide and indium arsenide have very high Hall coefficients (see Equation 1).

2. Shockley, W., *Electrons and Holes in Semiconductors,* (1950), 275-278. Φ_H is called the Hall coefficient.

3. These effects are dealt with for the cases of germanium and silicon in Gold, L. and L. M. Roth, "Galvanomagnetic Theory for *n*-type Germanium and Silicon: Hall Theory and General Behavior of Magnetoresistance," *Phys. Rev.*, **107** (1957), 358-364.

4. For such a solution in the d.c. case see Wick, R. F., "Solution of the Field Problem of Germanium Gyrator," *J. Appl. Phys.*, **25** (1954), 741-756.

5. Ohio Semiconductors, Inc., Types HS-31 and HS-51 devices.

6. In addition, encapsulation is usually required to protect the device from a contaminating environment, such as moisture.

7. Siemens and Halske AG, *Notes on Hall Generators,* (1957), 12-13.

8. Magnetoresistance is the resistance variation of a semiconductor with applied magnetic field.

9. For a more general approach see Van Der Pauw, L. J., "A Method of Measuring Specific Resistivity and Hall Effect of Discs of Arbitrary Shape," *Phillips' Res. Rep.*, **13** (February, 1958), 1-9.

10. Of course magnetoresistance makes this assumption not entirely valid. However, for completeness a voltage source input is being considered. In practice to insure linear multiplication a current source input must be used.

11. Minden, H. T., "Intermetallic Semiconductors," *Semiconductor Products,* **2** (February, 1959), 33.

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Zener Diode Circuits For Stable Transistor Biasing

Part 2

J. KABELL* V. H. GRINICH*

(*Continued from May 1961*)

In equation (27), (*Semiconductor Products*, May 1961, p. 48), R_e is the larger positive root of Eq. (28). The larger value is chosen in order to make R_2 as large as possible, and thus minimize the power drain of the circuit. For the minimum stability factor consistent with loading and operating point, the relation $R_c = \sqrt{R_c R_L}$ holds. In that case, the quadratic in R_e has only one solution.

In order to show the power savings obtained by the Zener diode bias method we calculate the circuit values and power consumption for the brute-force circuit that gives the same loading and stability factor as the diode case.

Substituting in numerical values we obtain for $S = 1.11$

$$R_e = 6K$$
$$R_c = 2K$$
$$R_2 = 1.28K$$
$$R_3 = 1.39K$$
$$R_b = 0.67K$$

This circuit requires a power input of approximately 68 *mw* of which 54 *mw* go into the divider portion of the bias circuit. The Zener bias scheme requires only 12 *mw* of *d-c* power giving an improvement in power drain of 5.7 to 1. Note that certain values of R_o R_L do not yield any physical solution.

A Tolerance Factor For Transistor Interchangeability

An important advantage of the Zener-diode biasing method is that the circuit operating point is made very insensitive to the properties of the transistor. This can be shown in introducing a new parameter for the circuit that specifies the sensitivity of *d-c* collector current, I_c, to variations in the *d-c* base current, I_b. This dimensionless quantity may be called a tolerability factor, T, where for the circuit of *Figs. 1, 2* and *3*

$$T = \frac{-\delta I_c}{\delta I_b} = 1 + \frac{R_b^*}{R_e} \qquad (29)$$

For the case of $E = 12v$, $R_L = 0.5k$, $I_e = 1$ *ma*, $V_{ce} = 4v$ and $I_b = 5$ μa in the standard resistive circuit *Fig. 1*, $T = 121$. For the Zener diode circuit of *Fig. 2* (and its equivalent, the brute force circuit of *Fig. 3*), $T = 1.11$. Thus if the base current of the transistor is not equal to the designed value of 5 μa but instead is 10 μa, then in the circuit of *Fig. 1*, I_c will change from 1.0 *ma* to 0.4 *ma* [0.4 *ma* = 1 *ma* — (121) (0.005 *ma*). This change of I_c reduces the dynamic range by a factor of 2.5, and may also be detrimental to the performance of the amplifier in terms of frequency response in the case of video and *if* amplifiers.

For the Zener-diode biasing method the collector current changes from 1.0 *ma* to 0.995 *ma* when the *d-c* base current increases from 5 μa to 10 μa. The low value found for the tolerance factor in the power drain case of Zener diode biasing means that the operating points of circuits can be accurately set with a minimum number of components and a minimum power drain.

Experimental Results

Circuits as shown in *Figs. 1* and *2* were made in order to compare bias stabilization for germanium alloy transistors. For the circuit of *Fig. 1*, $R_c = 5.6K$, and $R_b = 430K$. For the circuit of *Fig. 2*, $R_c = 1.6K$, $R_e = 4.3K$, $R_b = 680\Omega$ and $V_{bd} = 8.2V$ (the breakdown diode was a type where the r_{bd} of the diode varied from 540Ω at 15μa to 280Ω at 20μa). The percentage change of I_c over I_c at 25°C. is shown in *Fig. 9* for *2N140* germanium *p-n-p* alloy unit using both bias methods.

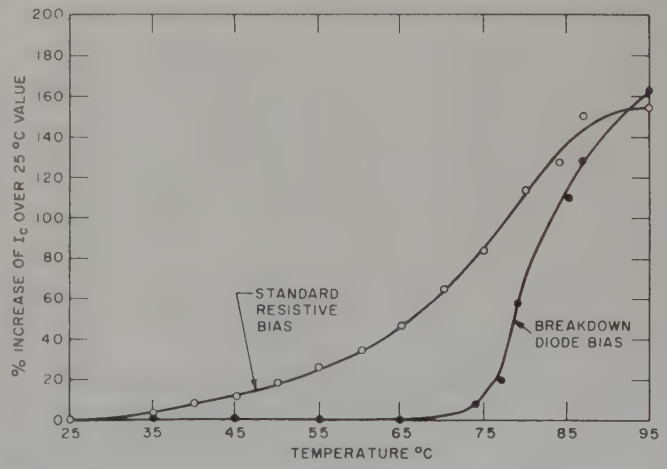

Fig. 9—Comparison of bias stabilization as a function of temperature. (Germanium transistors).

*Fairchild Semiconductor Corporation

* The relations between S and T are

$$S = \frac{T}{(T-1)(1-h_{FB})-1} \text{ and } T = \frac{h_{FB}\,S}{1-S(1-h_{FB})}$$

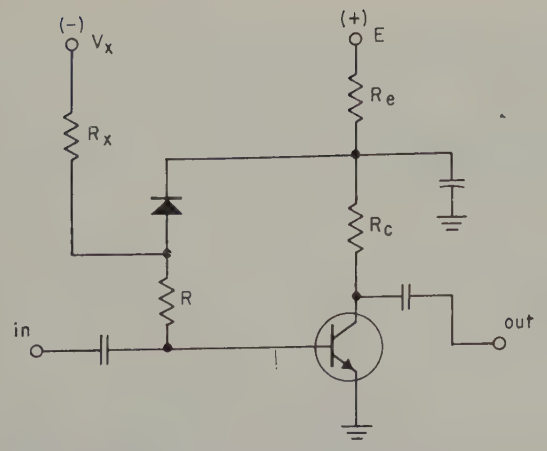

Fig. 10—Modification of the circuit of Fig. 2 for extended temperature range operation.

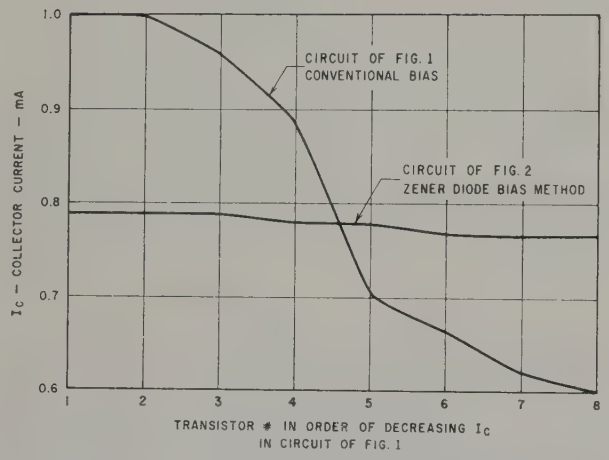
CIRCUIT OF FIG. 1
CONVENTIONAL BIAS
CIRCUIT OF FIG. 2
ZENER DIODE BIAS METHOD
I_C – COLLECTOR CURRENT – mA
TRANSISTOR # IN ORDER OF DECREASING I_C
IN CIRCUIT OF FIG. 1

Fig. 11—I_c as a function of transistor replacement.

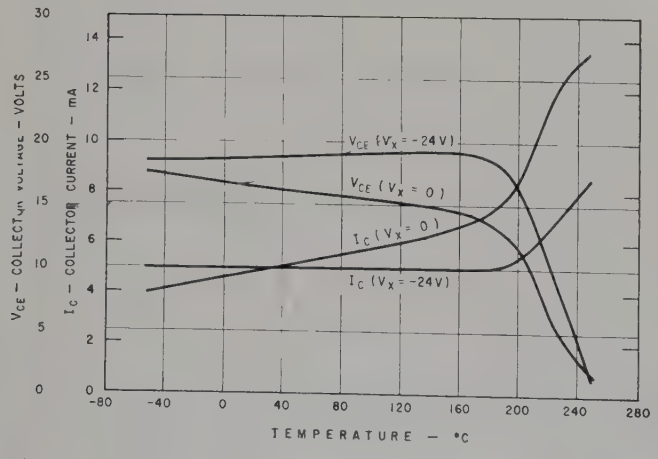

Fig. 12—Variation of I_c and V_{CE} with circuit temperature.

In order to show how the circuit responds to transistor replacement eight 2N104 units were plugged into the circuit of *Fig. 1* and into that of *Fig. 2*. The values of I_c for both circuits are given in *Fig. 11*. The maximum deviation using breakdown bias was 1.2%, while using standard resistive bias the maximum deviation from the mean was 24%.

The operating point for the Zener diode biasing method shifts because the current flowing through the diode becomes so low that insufficient voltage is built up across the diode. The design equations for diode current can be formulated by letting $I_c = h_{FB} I_e + I_{co}$, where h_{FB} is the common base *d-c* current gain for the transistor. Then $I_b = (1-h_{FB})\ I_e - I_{co}$.

In order to make I_b sufficiently large that the diode will be biased well into the breakdown region, we can do one or more of the following: (1) choose transistor replacement eight 2N104 units were plugged transistors having h_{FB} as small as possible, after considering the effect on signal gain, (3) operate with a large I_e (power drain and junction dissipation act as limits here) or (4) add a resistor between base and ground in *Fig. 2* in order to increase the diode current. (This in effect lowers the effective h_{FB} of the composite unit, transistor plus base-to-emitter resistor.)

In place of adding a resistor from base to emitter, a more advantageous site for the resistor R_x is from the junction point of diode and R_b to ground (*Fig. 10** with $V_x = 0$).

If one allows oneself the luxury of an additional power supply of opposite polarity to the collector supply in *Fig. 10*, the stability can be greatly increased. It should be noted that the current level required from V_x is determined only by the margins set on operating the diode into breakdown and hence can be an economical solution in cases of extremely high temperature environments, especially with the lower values of coupling and bypass capacitances that can be used in this scheme.

To demonstrate the above points a circuit was constructed using silicon transistors (2N697) in the circuit of *Fig. 10*. *Fig. 12* shows the variation of I_c and V_{ce} versus circuit temperature** for the case where V_x = zero and $V_x = -24v$. The circuits are obviously useful to beyond 200°C. with the case of $V_x = -24v$ being obviously superior. Of course, before using transistors at these temperatures reliability considerations should be investigated for all components. Nevertheless this does indicate the potential of this biasing scheme over a wide temperature range.

* Suggested by P. J. Beneteau of Fairchild Semiconductor Corporation.

** In this case both zener diode and transistor were placed in a variable temperature chamber.

Correction: Equation (23) given in Part 1, was erroneous. Thefollowing is the correct form of this equation:

$$S_{opt.} = \frac{R_L + (\sqrt{R_o} - \sqrt{R_L})^2}{(1 - h_{FB})\ R_L + (\sqrt{R_o} - \sqrt{R_L})^2} \qquad (23)$$

Switching Time Formulae For Single Diffused Mesa Transistors

ERNEST SEVERIN*

Formulae for the switching times of alloy transistors have previously been derived, and the expressions for double diffused devices have been indicated; but the results do not give satisfactory accuracies with the diffused-base, evaporated emitter devices.[1,2] In addition, these formulae do not state the switching times in terms of easily obtainable parameters. This article is intended to give the reader formulae necessary to calculate the four switching times: Delay, rise, storage, and fall—from either data sheets or easily measurable steady state quantities. Values calculated from these expressions should, with careful choice of parameters, be within 20% of measured values for single-diffused mesa units. Some or all the formulae can be applied with some success to other type devices; the accuracies to be expected are included in the explanation of each derivation.

THE BASIS FOR THESE DERIVATIONS is the standard lumped constant, T, equivalent circuit for diffused base transistors. This circuit, which is shown in Fig. 1, includes the important characteristics of these devices and is, in fact, a good equivalent circuit for all type transistors. The table below is composed of equations with which to calculate the lumped elements of diffused-base units.

Parameter Equations

r_b' = constant, base spreading resistance
r_e = $.026/I_e$, dynamic emitter resistance
C_{Se} = $1/2\,\pi\, f_T r_e$, emitter saturated capacitance
f_T = frequency where $|\, h_{fe} \,| = 1$

$$C_{Te} = \frac{C_1}{|\, V_{be} + \delta \,|^{\frac{1}{2}}}$$ emitter transition cap.

C_1 = C_{Te} at $|\, V_{be} + \delta \,| = 1$v
δ = contact potential, pos. for n-p junction, neg for p-n junction.
r_c = dynamic collector resistance.

$$C_{Tc} = \frac{C_2}{|\, V_{cb} + \delta \,|^{\frac{1}{3}}}$$

C_2 = C_c at $|\, V_{cb} + \delta \,| = 1$v

$$\alpha = \frac{\alpha_o e^{-jm\frac{f}{f_\alpha}}}{1 + j\frac{f}{f_\alpha}}$$

α_o = low frequency value of α, f_α = frequency where $|\, \alpha \,| = .707\, |\, \alpha_o \,|$
m = excess phase of α at f_α in radians.

In addition to these equivalent circuit parameters, the following quantities are needed:

$$h_{FE} = \frac{I_C}{I_B} \div \frac{\alpha_o}{1 - \alpha_o}$$ = d-c forward current transfer ratio common emitter

t_r and t_f = rise and fall times of pulse generator;
$V_{BE(O)}$ = *off* voltage base to emitter on transistor;
R_L = collector load resistance,

$$I_C = \frac{V_{cc} - V_{CE(Sat)}}{R_L}$$ = *on* collector current

I_{B1} = turn on base current
I_{B2} = initial turn off base current

$$f_T = \frac{f_\alpha}{1 + \alpha_o m}$$

τ = minority carrier lifetime in the collector region

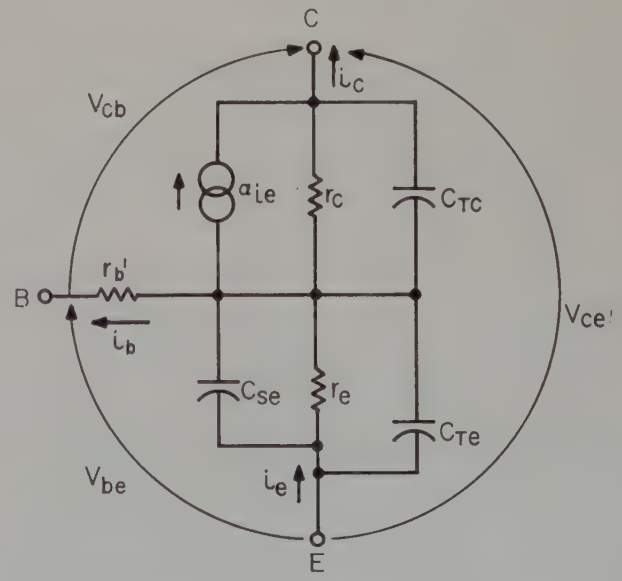

Fig. 1—Equivalent circuit for diffused base transistors.

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Semiconductor Components Division
Dallas, Texas

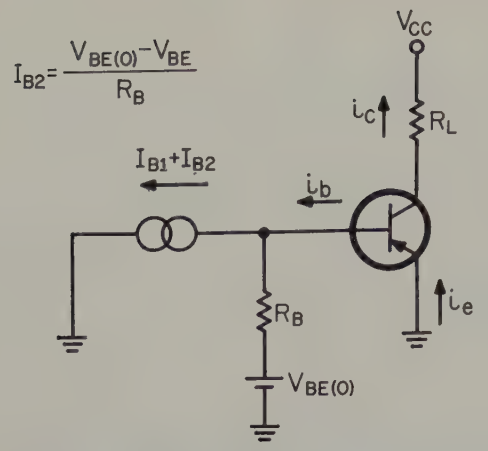


Fig. 2—Equivalent circuit for a switching circuit.

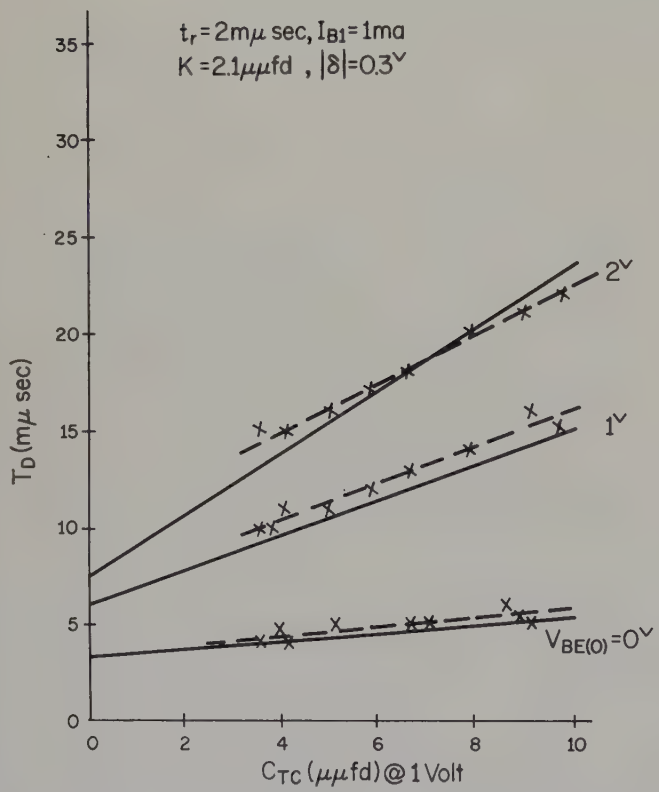


Fig. 3—Delay time in relation to collector transition capacitance; dotted lines are measured values.

Assumptions

1. Any switching circuit in which the transistor is to be evaluated can be put in the equivalent form of Fig. 2.
2. Values of h_{FE}, C_c, f_T, *and* τ can be found which are good averages for the voltage and current ranges used.
3. The rise and fall times of the pulse generator are at most only slightly longer than the delay time of the transistor.

Delay Time

The delay time of a transistor in a given circuit depends on the collector capacitance, the emitter capacitance, and the transition time in the base region. For the type mesa transistors being studied, the transition time is relatively short due to a very thin base region; only the itme required to charge the collector and emitter capacitances to bring the transistor into conduction will be considered.

The charge into the base, Q_D, required to bring the transistor into conduction is the sum of Q_{ED} and Q_{CD}, the charge into the emittor and collector, respectively. The result of charging these is a change of ϕ_{be} from $V_{BE(0)}$ to $[V_{BE(ON)} - I_{B1}r_b'] \div -\delta$.

Since V_{cc} is normally much larger than $V_{BE(0)}$, the change of C_c due to this small percentage change of voltage on the junction will be neglected. Therefore:

$$Q_{CD} = C_{Tc} \mid \Delta V_{bc} \mid = C_{Tc} \mid V_{BE(0)} + \delta \mid \qquad (1)$$

and

$$Q_{ED} = \int_0^{\mid V_{BE(0)}+\delta \mid} \frac{C_1}{(\phi_{be})^{\frac{1}{3}}\, d}\,(\phi_{be}) = 2\,C_1 \mid V_{BE(0)} + \delta \mid^{\frac{2}{3}} \qquad (2)$$

Therefore for:

$$\int_0^{T_D} i_b dt = QC + QE = \int_0^{t_r} i_b dt + \int_{tr}^{T_D} i_b dt$$

$$= \int_0^{t_r} \frac{\mid I_{B1} \mid}{t_r}\, tdt + \int_{tr}^{T_D} \mid I_{B1} \mid dt = \mid I_{B1} \mid \frac{t_r}{2}$$

$$+ \mid I_{B1} \mid (T_D - t_r) = \mid I_{B1} \mid T_D - \mid I_{B1} \mid \frac{t_r}{2}$$

$$= Q_C + Q_E \qquad (3)$$

$$T_D = \frac{t_r}{2} + \frac{1}{\mid I_{B1} \mid}\,(Q_C + Q_E)$$

$$T_D = \frac{t_r}{2} + \frac{2\,C_1}{\mid I_{B1} \mid} \mid V_{BE(0)} + \delta \mid^{\frac{2}{3}}$$

$$+ \frac{C_{Tc}}{\mid I_{B1} \mid} \mid V_{BE(0)} + \delta \mid \qquad (4)$$

The correlation between calculated and measured values of T_D is shown in Fig. 3. As in the equation T_D varies in a direct relation with $V_{BE(0)}$ and C_{Tc}. Samples could not be obtained with variable C_{TE}'s.

To modify this formula for other type devices, nothing need be changed for alloy type devices. The exponent of $|V_{BE(0)} + \delta|$ should be changed from ½ to ⅔ for double diffused devices.

Rise Time

Rise time is the time required for the transistor collector current, i_c, to go from .1 I_C to .9 I_C. The radian frequency at which the forward current gain is 3 db down in a transistor is:

$$\omega = \frac{1}{h_{FE}\left(R_L C_{Tc} + \frac{1}{2\pi f_T}\right)} \tag{5}$$

If i_c could assume any value, it would reach $h_{FE}I_{B1}$. So the equation for collector current during the transition period is:

$$i_c = h_{FE}I_{B1}\,(1 - e^{-\omega t}) \tag{6}$$

But i_c never reaches $h_{FE}I_{B1}$; it is cut off at

$$I_C = \frac{V_{CC} - V_{CE(ON)}}{R_L}$$

(see Fig. 4) and a formula for rise time is:

$$.9\ I_C = h_{FE}I_{B1}\,(1 - e^{-\omega T_R}) \tag{7}$$

The time to go from $i_c = 0$ to $.1\ I_C$ is neglected here since it is on the steep part of the exponential curve and is, therefore, very small. Solving (7) for T_R gives:

$$T_R = \frac{1}{\omega} \ln \frac{h_{FE}I_{B1}}{h_{FE}I_{B1} - .9\ I_C} \tag{8}$$

The ratio $h_{FE}I_B/I_C$ is called overdrive factor and $h_{FE}I_{B1}/I_C \simeq OD_1$. Substituting OD_1 for $h_{FE}I_{B1}/I_C$ and (5) for ω into (8):

$$T_R = \left(R_L C_{Tc} + \frac{1}{2\pi f_T}\right) h_{FE} \ln \frac{OD_1}{OD_1 - .9} \tag{9}$$

Fig. 5 shows the correlation between calculated and measured values of T_R. Notice that T_R varies somewhat with the inverse of h_{FE}. However, T_R is primarily a function of the response constants $\frac{1}{2}\pi f_T$ and $R_L C_c$. The intersection of curves such as those in Fig. 5 with the $C_{Tc} = 0$ axis are a function of f_T and the slopes of the curves are a function of R_L. Empirical values of both transition times (T_R and T_F) are higher than the theoretical values because of the rise time and capacitance inserted by the scope.

Equation (9) is also good for alloy and double diffused devices. For alloy devices, however, the equation for C_{Tc} becomes $C_{Tc} = K_2\ (V_{CB} + \delta)^{1/2}$.

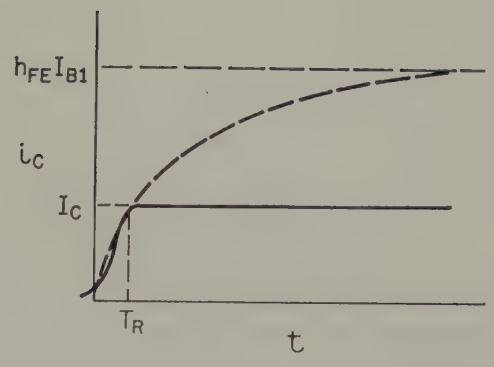


Fig. 4—Rise time for collector current, i_c.

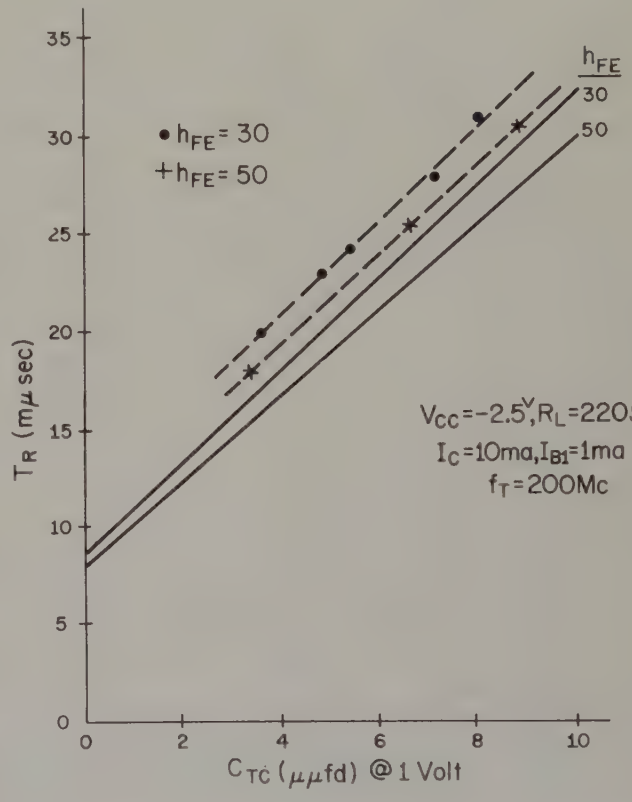


Fig. 5—Rise time in relation to collector transition capacitance; dotted lines are empirical values.

Storage Time

The storage time of a transistor in a saturating circuit is the time required for i_c to decrease from I_C to $.9\ I_C$ after i_b has reached 10% of the transition from I_{B1} to I_{B2}. The derivation presented here shows that for mesa devices this time depends on the response constants of the transistor and its collector body lifetime, since inverse alpha is nearly zero.

To review, Lax and Neustadter[3] showed that the time for a junction which was forward biased to become reverse biased when a reverse pulse is applied (the diode recovery time) can be found from the expression:

$$\operatorname{erf} \sqrt{\frac{T_r}{\tau}} = \frac{I_f}{I_f - I_r} \tag{10}$$

Where:

T_r = diode recovery time
τ = lifetime
I_f = forward current
I_r = initial reverse current (negative valued)

Grinich and Noyce[4] applied the concept to transistors by the use of the representation shown in Fig. 6. The equivalent transistor is composed of a transistor identical to the actual one and a diode with the same recovery characteristics as the base to collector junction of the actual transistor which carries the forward current of the collector base junction in saturation.

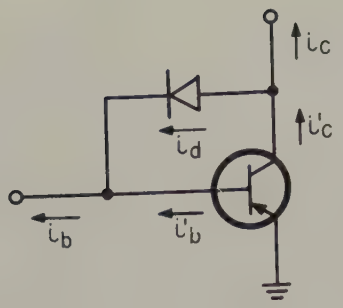


Fig. 6—Equivalent circuit for finding storage time.

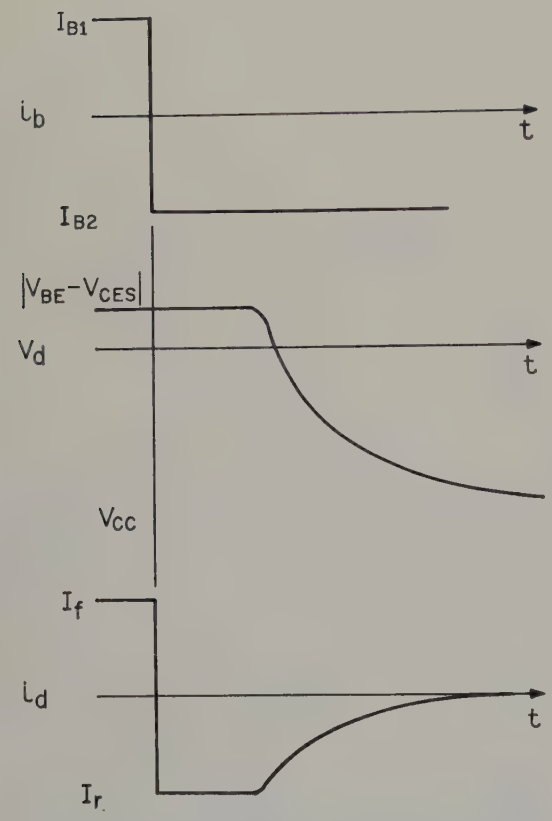


Fig. 7—Waveforms for Input, Diode Voltage and Diode Current.

Therefore:

$$i_b' = i_b - i_d \tag{11}$$

$$i_c' = i_c + i_d \tag{12}$$

$$\frac{i_c'}{i_b'} = h_{FE} = \frac{i_c + i_d}{i_b - i_d} \tag{13}$$

$$i_d = \frac{h_{FE}\, i_b - i_c}{1 + h_{FE}} \tag{14}$$

For most transistors $h_{FE} >> 1$; hence, equation (14) becomes

$$i_d = i_b - \frac{i_c}{h_{FE}} \tag{15}$$

While the transistor is turned on and in saturation, the diode is forward biased and

$$I_f = I_{B1} - \frac{I_C}{h_{FE}} \tag{16}$$

At the instant the base current is reversed, the equation becomes:

$$I_r = I_{B2} - \frac{I_C^*}{h_{FE}} \tag{17}$$

Now that I_f and I_r are expressed in terms of circuit values, T_r can be written on the same basis.

$$\operatorname{erf}\sqrt{\frac{T_r}{\tau}} = \frac{I_f}{I_f - I_r} = \frac{\dfrac{I_{B1}}{I_{B2}} - \dfrac{I_C}{h_{FE}\, I_{B2}}}{\dfrac{I_{B1}}{I_{B2}} - 1} \tag{18}$$

but: $\operatorname{erf}\sqrt{\dfrac{T_r}{\tau}} \doteq \sqrt{\dfrac{T_r}{\tau}}$ if $\dfrac{I_F}{I_F - I_R} \leq .8$

$$\therefore T_r \doteq \tau \left(\frac{I_{B1} - \dfrac{I_C}{h_{FE}}}{I_{B1} - I_{B2}} \right)^2 \quad \text{where} \quad I_{B1} \leq |\, 4\, I_{B2}\, | \tag{19}$$

Fig. 7 shows in sequence the input waveform, the diode voltage waveform, and the diode current waveform.

The diode current waveform can be approximated by the sum of two exponentials and will have the form of (11).

$$i_d(t) = I_r \left(K_1 e^{-\frac{a}{T_r} t} - K_2 e^{-\frac{b}{T} t} \right) \tag{20}$$

Average values for the coefficients and exponential multipliers in Eq. (20) have been found which are useful for the single diffused germanium mesas now available.

They are:

$$K_1 = 1.8, \qquad K_2 = 0.8, \qquad a = 0.6, \qquad b = 2$$

Taking the La Place transform of the transistor response equation

$$I_c(s) - i_c(+0) + \omega I_c(s) = \omega\, h_{FE} I_b(s) \tag{21}$$

and

$$I_c(s) = \frac{I_C}{s + \omega} + \frac{h_{FE}}{s + \omega}\, I_b'(s) \tag{22}$$

For transistors in a switching circuit

$$\frac{1}{\omega} = h_{FE} \left(R_L C_{Tc} + \frac{1}{2\,\pi\, f_T} \right) \tag{23}$$

It should be kept in mind that during the storage time period the collector base junction is near zero

*I_{B2} and I_r will have negative values.

bias, so C_c is large compared to its value at normal operating voltage.

The base current of the theoretical transistor is $i_b - i_d$. Hence, for the period starting at the time the base current of the actual transistor is reversed:

$$i_b' = I_{B2} - I_r\left(K_1 e^{-\frac{a}{T_r}t} - K_2 e^{-\frac{b}{T_r}t}\right) \quad (24)$$

Taking the La Place transform:

$$I_b'(s) = \frac{I_{B2}}{s} - I_r\left(\frac{K_1}{s+\frac{a}{T_r}} - \frac{K_2}{s+\frac{b}{T_r}}\right) \quad (25)$$

Substituting this expression into Eq. (25):

$$I_c(s) = \frac{I_C}{s+\omega} + \frac{\omega h_{FE}}{s+\omega}\left[\frac{I_{B2}}{2} - I_r\left(\frac{K_1}{s+\frac{a}{T_r}} - \frac{K_2}{s+\frac{b}{T_r}}\right)\right] \quad (26)$$

Taking the inverse La Place transform yields:

$$i_c(t) = h_{FE}I_{B2} + (I_C - h_{FE}I_{B2})e^{-\omega t} + (I_C - h_{FE}I_{B2}) \left[\frac{K_1\omega}{\omega - \frac{a}{T_r}}\left(e^{\frac{a}{T_r}t} - e^{-\omega t}\right) - \frac{K_2\omega}{\omega\frac{b}{T_r}}\left(e^{\frac{b}{T_r}t} - e^{-\omega t}\right)\right] \quad (27)$$

For the case of $\omega >> b/T_r > a/T_r$, that is the case where T_s depends more on the lifetime than the response-time constants:

$$i_c(t) = h_{FE}I_{B2} + (I_c - h_{FE}I_{B2})\left(K_1 e^{-\frac{a}{T_r}t} - K_2 e^{-\frac{b}{T_r}t}\right) \quad (28)$$

Since $K_1 e^{-\frac{a}{T_r}t} >> K_2 e^{-\frac{b}{T_r}t}$ for $t \geq T_r$, and $T_s \doteq T_r$ for $\omega >> \frac{b}{T_r} > \frac{a}{T_r}$, then $.9\ I_c = h_{FE}I_{B2} + (I_c - h_{FE}I_{B2})$ $K_1 e^{-\frac{a}{T_r}T_s}$

$$T_s = \frac{T_r}{a}\ln K_1 \frac{I_c - h_{FE}I_{B2}}{.9\ I_c - h_{FE}I_{B2}} \quad (29)$$

For the case of $b/T_r > a/T_r >> \omega$, that is the case where T_s is more dependent on the response speed, the equation becomes

$$i_c(t) = h_{FE}I_{B2} + (I_c - h_{FE}I_{B2})e^{-\omega t} + (I_c - h_{FE}I_{B2})\left[\frac{K_1}{a} - \frac{K_2}{b}\right]\omega T_r e^{-\omega t} \quad (30)$$

and solving for storage time

$$T_s = \frac{1}{\omega}\ln\frac{I_c - h_{FE}I_{B2}}{.9\ I_c - h_{FE}I_{B2}}\left[1 + \left(\frac{K_1}{a} - \frac{K_2}{b}\right)\omega\ T_r\right] \quad (31)$$

Transistors with identical h_{FE}'s in a given switching circuit will have storage times which vary with ω and T_r as shown in Fig. 8. The lower solid line was calculated from Equation (29) where T_s is solely dependent on τ; the upper solid curve was calculated from Equation (31) where T_s is mostly dependent on ω. Notice that the empirical or dashed curve asymptotes to the two solid curves at its extremes. The range of C_c's over which the transition occurs depends on τ, R_L, and h_{FE}.

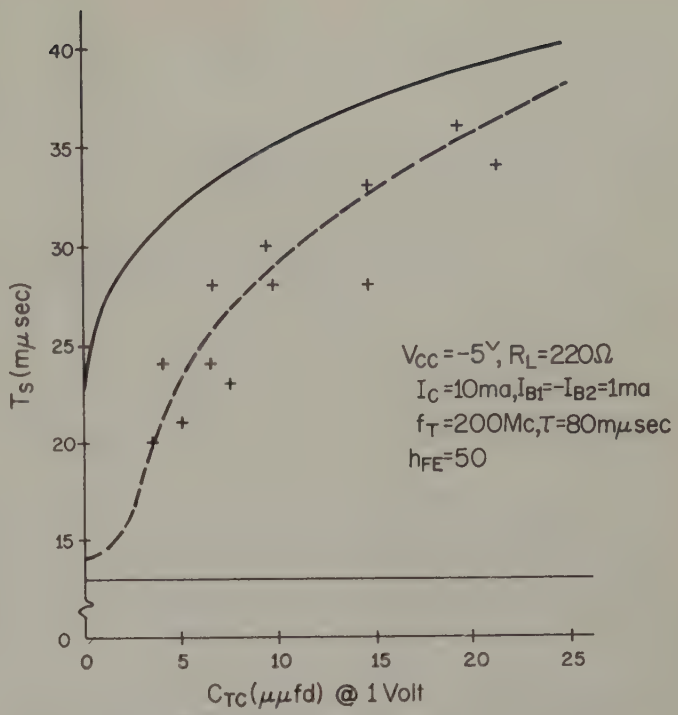


Fig. 8—Storage time in relation to collector transition capacitance; dotted line is measured values.

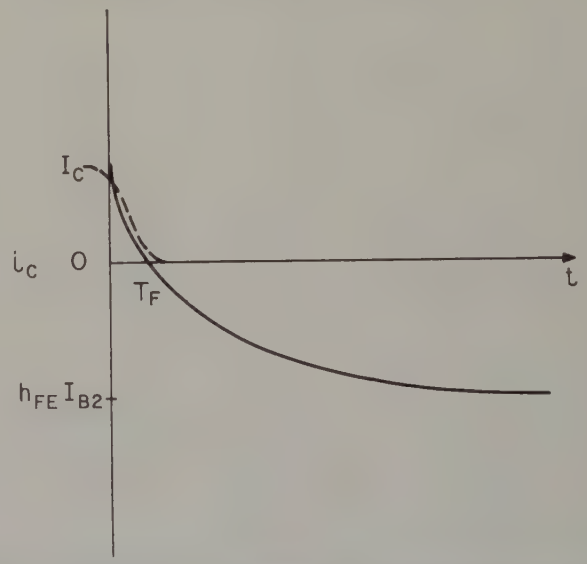


Fig. 9—Fall time for collector current—theoretical and actual waveforms.

The generalized Equation (27) may be applied to any diffused base mesa transistor if values of K_1, K_2, a, b and τ are known. The basic concept, of course, applies to all mesa transistors, that is: The storage time depends on a combination of h_{FE}, C_c, f_T, and collector body lifetime.

Fall Time

Fall time is the time required for the transistor col-

lector current i_c to drop from .9 I_C to .1 I_C. The response is similar to that which occurs during rise time and depends on ω. If i_c could assume any value, and I_{B2} were maintained, it would reach $h_{FE}I_{B2}$. The equation for the collector current would be:

$$i_c = h_{FE}I_{B2} + (I_C - h_{FE}I_{B2})e^{-\omega t} \qquad (32)$$

However, i_c could never reach $h_{FE}I_{B2}$ since it cannot conduct in the reverse direction. The theoretical and actual waveforms are shown in Fig. 9. Notice that the times where i_c is .9 I_C and .1 I_C on the actual curve are about the times where i_c is I_C and 0 respectively on the theoretical curve. The equation may, therefore be written:

$$0 = h_{FE}I_{B2} + (I_C - h_{FE}I_{B2})e^{-\omega T_F} \qquad (33)$$

Since there is a rounding off of the actual waveform at the extremes of the transition time, therefore

$$T_F = \frac{1}{\omega} \ln \frac{I_c - h_{FE}\, I_{B2}}{-h_{FE}I_{B2}} = \frac{1}{\omega} \ln \frac{1 + OD_2}{OD_2} \qquad (34)$$

The ratio $-h_{FE}I_{B2}/I_C = OD_2$ and is positive. So:

$$T_F = \left(R_L C_{Tc} + \frac{1}{2\pi f_T}\right) h_{FE} \ln \frac{1 + OD_2}{OD_2} \qquad (35)$$

Fig. 10 shows the correlation between calculated and measured values of T_F. T_F varies as a direct function of h_{FE} in a similar manner to the way T_R varies as an inverse function. Just as T_R, T_F is primarily a function of the response parameters and in fact varies in exactly the same way with these parameters.

Equation (35) is good for alloy and diffused devices as well. The same rules of conversion are true for T_F as were used for T_R.

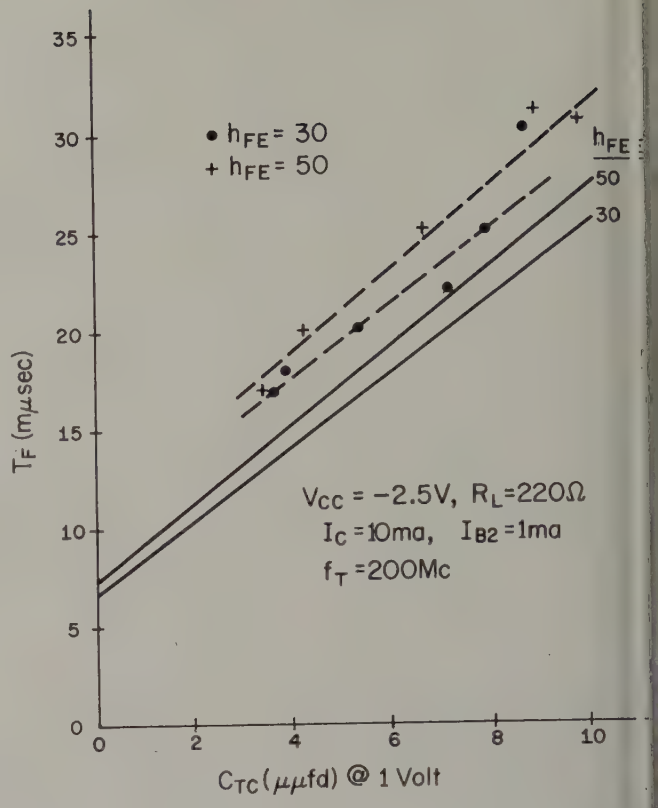


Fig. 10—Fall time in relation to collector transition capacitance; calculated and empirical values.

Conclusion

Formulae are now available for calculating the four switching times from easily obtainable parameters. The correlation of measured and calculated values shows that the target accuracies were realized. The most serious difficulty in applying these expressions is the proper choice of parameter values for the conditions during the time being calculated.

Even more important perhaps than the ability to accurately anticipate the switching times of a transistor in a given circuit, is the easily discernible importance of various transistor parameters to each of the four times. If the collector-base diode recovery time is small compared to the storage time, then three of the four times (T_R, T_S, and T_F) are inverse functions of ω. The expression for $1/\omega$ might be reviewed here in the light of its importance.

$$1/\omega = \left(R_L C_{Tc} + \frac{1}{2\pi f_T}\right) h_{FE}$$

For most of the modern ultra-fast switching transistors, C_{Tc} is of greater consequence to ω than is f_T. C_{Tc} in turn has a direct relation to junction area.

The fourth switching time, T_d, is a function of all the capacitance; so it, too, is a function of area.

It should be obvious then that once the lifetime and base width have reached their practical minimums, the only way to reduce switching speed is to make the active portion of the transistor smaller. Reducing the junction also, of course, brings on other problems, mostly with d-c parameters, but these will have to be tolerated if maximum performance is desired.

References

1. Ebers and Moll, "Large Signal Behavior of Junction Transistors," *Proc. I.R.E.*, pp. 1761-1772, December 1954.
2. Grinnich and Noyce, "Switching Time Calculations for Diffused Base Transistors," *I.R.E. Wescon Convention Record, Part 3, Electron Devices*, pp. 141-147, 1958.
3. Lax and Neustadter, *Journal of Applied Physics*, Vol. 25, No. 9, September, 1954.
4. Grinich and Noyce, op. cit.

A New Method For Measuring The Volume Resistivity of Semiconductor Material

G. L. ALLERTON* J. R. SEIFERT*

In the manufacture of transistors and other solid state devices, silicon and germanium material is manufactured to have a volume resistivity required for the device being manufactured. A very accurate measurement of resistivity is required to determine device parameters and processing methods. The four point probe method now universally used for these measurements can be replaced with a microwave measurement at certain ranges of resistivity and slice thickness of material with an increase in accuracy and speed of measurement.

THE SEMICONDUCTOR INDUSTRY now uses a four point probe method shown in Fig. 1 which applies a current through the outside probes and measures the voltage drop between the two inner probes with a potentiometer. With a knowledge of slice thickness, diameter of slice, and probe spacing the resistivity may be computed. [1,2]

A new method has been developed which is used to measure the resistivity at microwave frequencies. The advantages of the new method are:

1. Elimination of the four point probe and possible damage to the material by it.
2. Confinement of the measurement to a depth of material close to the surface as determined by the depth of penetration at microwave frequencies.
3. Faster and more accurate measurements under conditions of manufacturing usage.

*Western Electric Co., Allentown, Penna.

Depth of Penetration

Figure 2 shows the depth to which microwave signals are effectively confined for different values of resistivity of the material being measured.[3,4] This provides a great advantage when the material being tested is thicker than the penetration depth. For slices 0.007 inch thick measured at 9,000 megacycles this applies to material 0.1 ohm cm. or lower. For 0.018 inch thick slices measured at 9,000 megacycles, this applies to material 0.6 ohm cm. or lower. In these cases the measurement of slice thickness is unnecessary, this saves time and eliminates another source of error. For material of higher resistivity, the slice thickness must be measured and is used to determine the resistivity.

Figure 3 is the test fixture on which is laid a one inch diameter slice of silicon semiconductor material 0.007 inches thick. Beneath this slice is a 0.218 inch by 0.400 inch orifice coupling to a high Q transmission type cavity resonant at 9,000 megacycles. It loosely couples

Fig. 1—Four point probe.

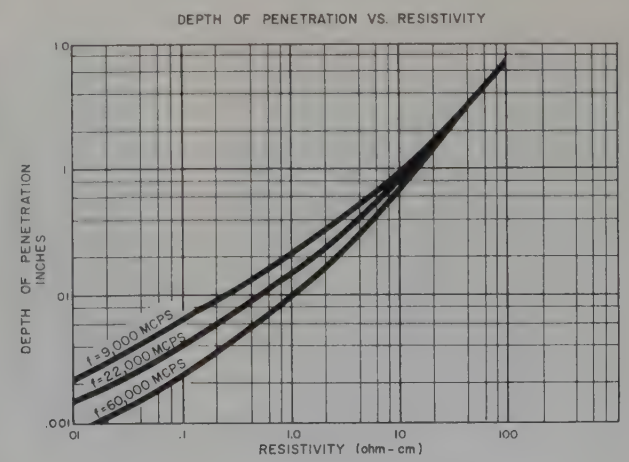


Fig. 2—Depth of penetration vs. resistivity.

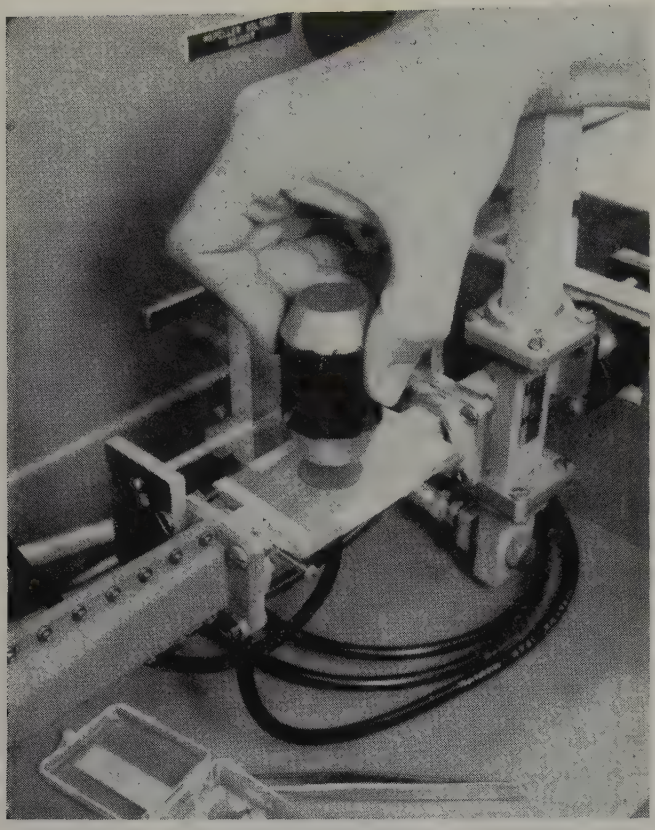


Fig. 3—Test fixture.

two transmission lines. The slice so loads the cavity that the signal transmitted through the cavity increases as the resistivity of the sample decreases. In Fig. 3 a small weight is being placed upon the very light slice to increase the reproducibility of measurements. When the slice is thinner than the depth of penetration a weight can be used containing an insert of 100 ohm cm. or similar material to provide a relationship shown in Fig. 4. Despite the fact that this microwave system is calibrated with samples whose resistivity is originally determined by the 4 point probe method, it has been found to give more accurate measurements under conditions of usage in a manufacturing plant in certain resistivity ranges.

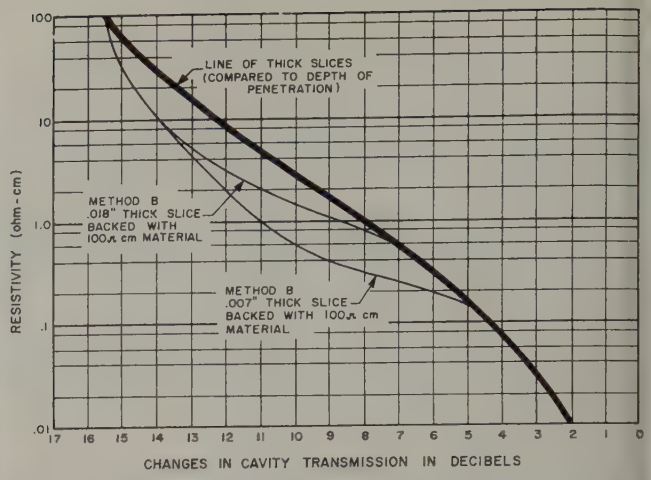

LINE OF THICK SLICES (COMPARED TO DEPTH OF PENETRATION)
METHOD B .018" THICK SLICE BACKED WITH 100Ω cm MATERIAL
METHOD B .007" THICK SLICE BACKED WITH 100Ω cm MATERIAL
RESISTIVITY (ohm-cm)
100
10
1.0
.1
.01
17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
CHANGES IN CAVITY TRANSMISSION IN DECIBELS

Fig. 4—Resistivity vs. changes in cavity transmission.

References

1. F. M. Smits, "Measurement of Sheet Resistivities with the Four-Point Probe," Bell Syst. Tech. J., Vol. 37, May 1958, pp. 13-20.
2. Valdes, L., "Resistivity Measurements on Germanium for Transistors," Proc. I.R.E., Vol. 42, Feb., 1954, p. 420.
3. Edward C. Jordan, "Electromatic Waves and Radiating Systems," third printing, Prentice Hall, Inc., New York City, p. 132, 1955.
4. G. L. Allerton and J. R. Seifert, "Resistivity Measurements of Semiconductors at 9,000 M.C.," June 1960 Conference on Standards and Electronic Measurements at Boulder, Colorado.

ERRATA

The following error appeared in the article "Flow Graph Analysis—Further Advantages." (November, 1960)

In equation (10) on page 34, the term

$$-h_{re}\, h_{oc}\, RR_L/h_{ic}$$

should not appear in the denominator. The conclusions are not affected since this term is subsequently dropped as negligible.

Figures 5 and 8 in the article "The Use of Silicon Junction Diodes for the Protection of A-C and D-C Meter Circuits" were in error. (March 1961).

The correct versions are shown at the right.

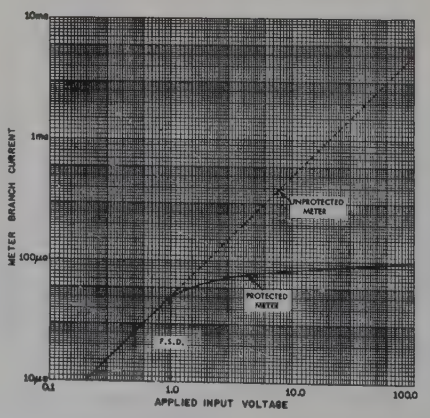


Figure 5

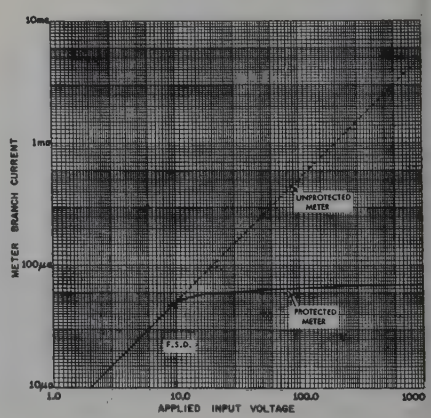


Figure 8

INDUSTRY REPORT

MATERIALS AND MACHINERY USED IN THE SEMICONDUCTOR INDUSTRY

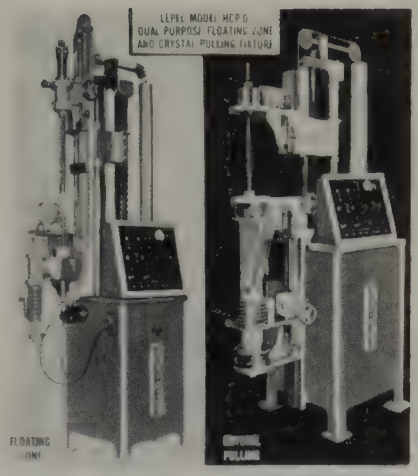
This report has been prepared by the Marketing Division of SEMICONDUCTOR PRODUCTS with the cooperation of many leading manufacturers in the semiconductor industry. It is intended to report, as accurately as possible, the existing status of suppliers of raw materials, production equipment and machinery to the industry.

Suppliers listed in this survey were mentioned one or more times on questionnaires filled out by purchasing agents in the industry as being their current source of supply. The report is not intended as a recommendation or advertisement for any company mentioned.

Germanium—Although the use of germanium by manufacturers in the semiconductor industry has dropped from 85% to 70%, it remains the largest primary material used. Eagle Picher holds its number one position as the largest raw material supplier while Sylvania's Chemical & Metallurgical Div. leads in the area of processed germanium. Knapic Electro-Physics, American Metal Climax and Semi-Metals rank next in the field. Other manufacturers such as Rare Metal Derivatives and United Mineral & Chemical Co. supply this material but in lesser quantities.

Silicon—The use of silicon has been increased in the past year, and it is still the second largest single material used by the semiconductor industry. Three suppliers have taken the lead in supplying silicon: Merck, Grace and DuPont. Knapic Electro-Physics and Texas Instruments are in close contention, although it must be taken into consideration that Texas Insruments uses a great deal of its own silicon since it is the largest semiconductor device manufacturer.

There are also several large device manufacturers who have their own chemical divisions supplying them with



Floating Zone Purifier and Crystal Puller. (Lepel High Frequency Laboratories, Inc.)

silicon but who have a sufficient surplus remaining for sale to the industry. Sylvania, Allegheny Electronic Chemicals, Tang Industries, Trancoa and Mallinckrodt Chemical have made much headway and are growing factors in the silicon field. General Electric and United Mineral & Chemical Co. may also be included, but not to any great extent.

Chemicals—Since there are a great many types of chemicals used in the industry, most device manufacturers use two or three suppliers to fulfill their needs. Allied Chemical retained the number one position in supplying chemicals while J. T. Baker and Mallinckrodt are extremely close seconds. Fisher Scientific, DuPont, Doe & Ingalls and Braun Chemical Co. continue to do a large volume of business in the chemical field.

Other suppliers are Merck & Co., Becco, Kern Chemical, Matheson, Coleman & Bell, Union Carbide, Harshaw Chemical, Lehigh Valley Chemical, Buston-Cross, Peerless Oil, Berg Chemical, United Mineral & Chemical, Tenso-Lab and Sessions-Gifford Co.

Alloys—Alloys Unlimited appears to be the largest supplier of alloys and Alpha Metals is quite close to equal standing with them. Accurate Specialties and Semi Alloys rank next. Cominco, Allegheny, Sigmund Cohn, Secon Metals, Indium Corp., and Nesor are also doing a considerable volume of business in this field. Other names receiving a small segment of business are Metals and Controls and Handy & Harman. It must be noted, however, that many manufacturers list a number of suppliers, and different types of metals and alloys are used for different applications.

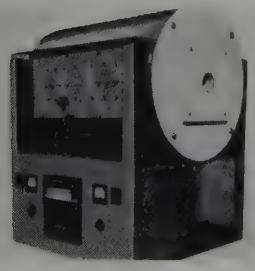
Crystal Growing Equipment—Probably less than 50% of the semiconductor device manufacturers grow their own crystals. Of this percentage, the majority have indicated that they make their own machinery for this purpose.

Kahle Engineering is the major factor in this area with Hoffman Electronics and N.R.C. Equipment Corp. sharing the majority of business in this segment of the industry. Other independent manufacturers of crystal growing equipment are Philco, Westinghouse, Lepel, New York Air Brake, Alpha Metals, Accurate Specialties and North American Electronics.

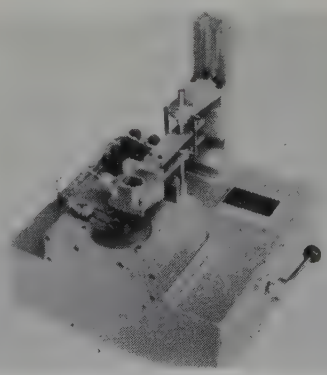
Vacuum Pumps—Most manufacturers use vacuum pumps in large quantities. Kinney Mfg. (Division of N. Y. Air Brake) seems to be receiving the volume of this business. W. M. Welch is receiving a fair volume, as are Veeco Vacuum and N.R.C.

Other companies engaged in this field are F. J. Stokes, Consolidated Electrodynamics, Braun Chemical, Harshaw Scientific, Ajax, Macalaster-Bicknell, Consolidated Vacuum, and Howe & French.

Furnaces—With very few exceptions, furnaces are used in extremely large quantities. Standouts in this field are Hevi-Duty and Lindberg Engineering. Also doing a comparatively large volume of business in the field are BTU, Blue "M" Engineering, C. I. Hayes and Pereny. Other producers include Lansdale Equipment (Div. of Philco Corp.), Temperature Engineering, Sandland Tool & Machinery, Lepel, Chafin & Assoc., N.R.C. Equipment, G.E. Induction Heating Div., Macalaster-Bicknell, Northeast Mfg., Sargeant



Electric Furnace. (Despatch Oven Co.)



Resistivity Test Set. (Semimetals, Inc.)

Water Cooled Oven.
(Tri-Metal Works Inc.)

& Wilbur, Howe & French, Scientific Glass Apparatus, Electric Hotpack, Despatch Ovens, Trimetal Works and C. M. Mfg.

Test Instruments—It is difficult to analyze this segment of the report due to the broad nature of the category. Tektronix seems to have cornered the market to a very large extent with Hewlett - Packard and Wallson its closest competitors. Other companies include Electronic Measurements, John Fluke Mfg., Philco Corp. (Lansdale Div.), Beckman Instruments, Dynatran, R.C.A., Electro - Instruments, Mosley Company, Boonton Electronics and many others too numerous to mention.

Wire and Leads—Although a great many manufacturers were included in this category, Sigmund Cohn Mfg. remains the outstanding leader. Secon Metals, General Electric, Consolidated Reactive Metals, Engelhard Industries and Nesor Alloy are doing a large volume of business in this category.

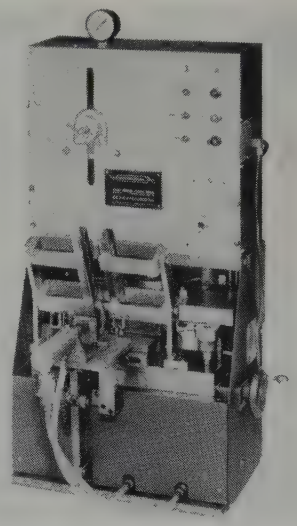
Art Wire & Stamping, Sylvania, Alloys Unlimited, Alpha Metals are also in this field and as in the previous category, many, many more which we are unable to list.

Seals and Enclosures—Since the average manufacturer uses between 4 and 7 suppliers in this category, it was impossible to compile all the material and come up with a reasonable selection of the major suppliers.

Welding Equipment—The Taylor Winfield Corp. seems to have taken over the lead in this category with Thomson Electric Welder, Federal Tool and Raytheon mentioned with regularity. Others mentioned were Philco, Hughes, Arizona Welding, National Electric Welding, Weldmatic, Ayles Welding, Denton & Anderson, New England Welding and P&H.

Environmental Test Chambers—In the past year, Tenney Engineering Co. has remained the leader in the field of environmental test chambers. Statham Developmet Company has taken over a large segment of the business with Labline, Temperature Engineering, Grieve-Hendry, Guardite Co., Conrad, Bristol Co. and NRC Equip. Corp. also having been mentioned. Although few in number, some device manufacturers build their own equipment.

Marking Machines—The Markhem Machinery Company continues to corner the market in this field, receiving approximately 85% of total volume with Popper & Sons also mentioned.

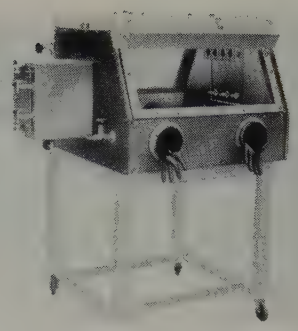


Automatic Lead Straightener.
(Design Tool Co., division of Federal Mfg. and Engineering Co.)

Glass Beading Machines—Since this machinery is used in producing specialized semiconductors, the majority of manufacturers cannot yet use this equipment. Kahle is actually the largest single supplier although Philco, Swanson Erie, Eisler and Federal Tool were mentioned.

Orientation Systems—It appears that the use of orientation systems by manufacturers has decreased. Those manufacturers still using this equipment obtain it mainly from Micromech.

Ceramics—Various types of ceramics and ceramic products are used by about 40% of the device manufacturers, due to the great variety of applications in the industry. American Lava remains the largest single supplier, with Mitronics, H. F. Coors and General Ceramics having taken great strides in the field. Also mentioned are Engelhard Industries, Fusite, Hercon, Western Gold & Platinum, Technical Ceramics, Centralab, Duramic Products, Frenchtown Porcelain, Du-Co Ceramics and C.F.I.



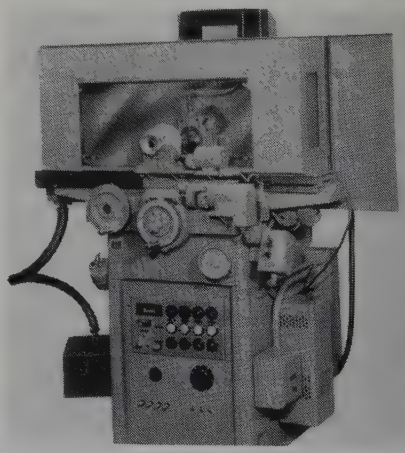
Double Faced Glove Box.
(Kewaunee Scientific Equipment)

Carbon Products—Carbon products continue to play an important part in the refining of raw materials for transistor and diode production. United Carbon holds its lead in this field, with Pure Carbon making tremendous strides as well. Others mentioned were National Carbon, Stackpole Carbon, Textool Products, Ohio Carbon, Ultrasonic Precision, Johnson Mfg., Transtronic Mechanical, Adolf Bauer, Parker-Hartford, Speer Carbon and Superior Carbon.

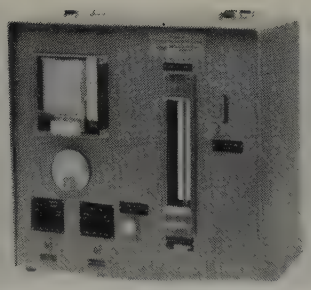
Epoxy Resins—These resins are used in the potting or sealing of semiconductor devices. Our survey indicates that Epoxy Products Co. is the largest single supplier of epoxy resins. Other companies mentioned were Minnesota Mining, DuPont Corp., Dow Chemical, Permacel, Armstrong, Philadelphia Resin, M. A. Bruder & Co., Shell Chemical Corp., Emerson & Cumming, Furane Plastics, Hysol, Epoxylite, Norrich Plastics, Smooth-On, and Polymer Industries.

Wafering Machinery—The Micromech Mfg. Company has taken such tremendous strides in this field, that it has taken over the lead as the largest single supplier of wafering machinery. Do-All is receiving a large share of the business with Fitchburg, Kulicke & Soffa, Nichols, Syntron, Reid Brothers and Brown & Sharpe also mentioned.

Pulse Generator.
(Tektronix, Inc.)



Slicing Machine.
(Reid Bros., Inc.)



Moisture Analyzer. (Manufacturers Engineering and Equipment Corp.)

Quartz—The third most essential material in the growing of crystals is quartz. General Electric and the Amersil Division of Engelhard Industries continues as the leading suppliers with Thermal American Fused Quartz Co., Corning, Knapic & Grace also mentioned.

Dry Boxes—Although the majority of manufacturers in the semiconductor industry continue to develop their own dry boxes, the number of independent suppliers seems to be on the increase. Temperature Engineering remains the leading supplier with Philco Corp. (Lansdale Div.), Kewaunee Scientific, Ray Products, Hull Corp, Duralab Equipment, Metalab Equip., Textar Plastics and Gruenberg Electric receiving some volume of business.

Microscopes—Microscopes represent an important factor in the production of semiconductor devices both on the production line as well as in research. American Optical seems to have taken over the lead with Bausch & Lomb second. Nikon, Inc., Braun Chemical and Seiwa Trading were mentioned with some regularity and Macalaster-Bicknell, Carl Zeiss Co., Unitron, and Opto-Metric Tools also in the picture.

Ultrasonic Cutting Tools—The great majority of manufacturers have continued to use this equipment, but as compared to the 90% of last year, the percentage has fallen off considerably. Raytheon and the Sheffield division of Bendix remain the major factors in the field.

Micromanipulators—The use of micromanipulators has increased to some extent as compared to the previous year's survey. Kulicke & Soffa Mfg. seems to have cornered the market in this field, with Philco (Lansdale Div.), C. A. Brinkman and DoAll also mentioned.

Water Demineralizing Equipment—A very important segment of the production equipment category, water demineralizing equipment has two leading sources throughout the industry, these being Penfield Manufacturing Co., and Barnstead. Other firms supplying equipment of this type are L. A. Water Conditioning, General Ionics, Permutit, Graver, Cilligan, Hanstan Chemical, Illinois Water Supply and Infilco.

Gases—It appears that more than 80% of the total volume of gases supplied to the semiconductor industry is obtained from either Air Reduction Co. or Linde Division of Union Carbide. Other firms in the picture are Burdett Oxygen, Dye Oxygen, National Cylinder Gas Co., Ayles Welding, Thomas Edison Gas Co., Matheson and General Dynamics.

Dessicant Dryers—This is a category with no single primary source of supply. The following firms obtain small shares of the total volume: Braun Chemical Co., C. I. Hayes, Engelhard Industries, Pittsburgh Lectrodryer, C. M. Kemp Co., Howe & French,

Coated Strip for Bonding Semiconductor Devices. (Alpha Metals, Inc.)

Scientific Glass Apparatus, Bristol Labs., U.S. Dynamics and Trinity Equipment Corp.

Laboratory Uniforms—It is quite apparent that no semiconductor manufacturer can operate without lint-free, dust-free uniforms for laboratory operation, and the following manufacturers are available as sources of supply: Worklon, Inc., Angelica Uniform Co. of California, Independent Garment Supply Co., Egineering Supply Co., Industrial Towel & Uniform Service, Suburban Coat & Apron Co., Apollo Coat & Apron Supply Co., University Rubber Co., Century Linen and Mary Roche.

Laboratory Furniture—This, again, is a category with a pretty much diversified source of supply, no single company getting a majority of the total volume The following firms were mentioned: Kewaunee Scientific Equipment, Braun Chemical, Clico Chemical, Philco Corp., Duralab Equipment, Crandall Cabinets, George Hamilton Mfg., Howe & French, Scientific Glass, T. H. Von Kamecke, Bel-Art Products, Fisher Scientific, Metalab and Ajusto.

Cutting Wheels—A major original equipment and replacement product in semiconductor material processing, the cutting wheel group is outstandingly dominated by the Norton Company with Navan Products a second large source of supply. Other suppliers listed

Vacuum Pencil for Handling Small Parts. (Kulicke and Soffa Mfg. Co.)

were DoAll, Garrett Supply, Felker Mfg., Maurice S. Dassau Co., Chandler & Farquhar, Rudel Machinery, Sample Marshall Labs, and Mid Island Supply.

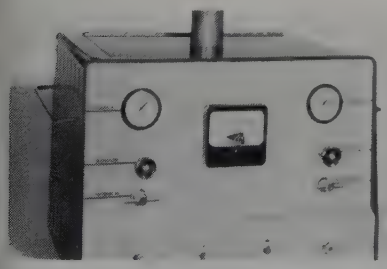
Lapping Machinery—The largest single supplier of lapping equipment in the United States is Crane Packing, with P. R. Hoffman and Dallons Laboratories also doing a volume business in this field. Other suppliers listed were Speedlap, Buehler and Strausbaugh.

Program Controllers—The outstanding suppliers of program controllers to the semiconductor industry are Minneapolis Honeywell, West Instrument Corp. and Leeds & Northrup. Other suppliers listed were Wheelco Division of Barber-Coleman, General Electric, Norman Bragar and American Electric Furnace.

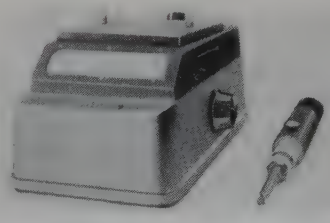
Metal Plating—It has become quite apparent that most semiconductor manufacturers rely on local firms to do their metal plating. The following companies were listed in this category: Chem. Research, Burton Silverplating, Philco (Lansdale Div.), Bayside Industries, International Plating, Newport Plating, Engelhard Industries, Sel Rex Corp., M&V Electroplating, F. M. Callahan & Son, C&C Electroplaters, Harper-Leuder, Spectranome and Giering Metal Finishing.

Acknowledgment

The semiconductor industry is growing and as other raw materials or production equipments become employed, these categories will be added to future reports. We wish to thank the many purchasing agents, advertising managers, sales managers and other executives throughout the semiconductor industry without whose cooperation this report would not have been possible.



Hydrogen Purifier. (Milton Roy Co.)



Thermoelectric Probe. (Electro Impulse Laboratory.)

APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST NO. 66

Circle No. 199 on Reader Service Card

Transistor Noise Figure; Semiconductor Div. of Tung-Sol Electric Inc., Newark, N.J. (K. Bahr)

The noise factor, or noise figure, is a quantity which compares the performance of an actual amplifier with an ideal or noiseless amplifier. It can be defined as the ratio of the total noise output power to that component of the noise output power due to the thermal noise in the source.

The noise factor of a transistor is a function of the d-c operating conditions, the source resistance R_g and the frequency f. Typical curves of NF vs f and NF vs R_g for modern alloy junction r-f transistors are shown in *Fig. 66.2*.

The low frequency noise up to about 1 *kc* in *Fig. 66.2* is called flicker noise. It follows approximateely the $1/f$ law. A clean surface and low leakage are essential to minimize flicker noise.

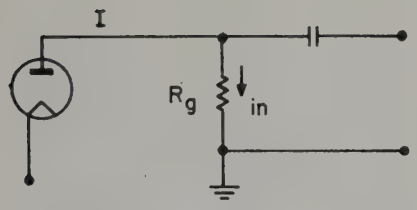


Fig. 66.1—Circuit for noise current.

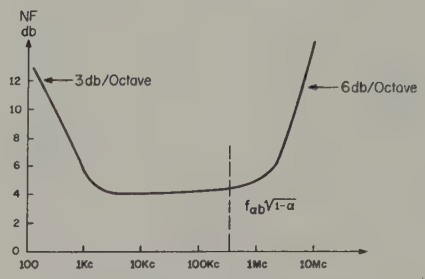


Fig. 66.2—Noise vs. frequency.

The flat portion of the curve in *Fig. 66.2* is determined by the shot noise characteristics of the transistor. Shot noise is frequency independent up to the frequency where the common base forward current ratio decreases. For low shot noise a high α cut-off frequency, high gain and a low extrinsic base resistance r'_b are required.

The noise factor of a transistor is the same in the common base and the common emitter configuration. The common emitter configuration is preferred since the optimum noise source resistance and the resistance for the matched condition are in the same order of magnitude.

For the noise figure measurement the noise diode method is generally preferred to the single frequency method, since it eliminates an accurate bandwidth measurement and the type of noise indicator is not critical as it has to read only voltages of similar characteristics, i.e. white noise.

Fig. 66.3 shows the block diagram of a noise figure test set.

The noise current i_n in *Fig. 66.1* is

$$i_n = \sqrt{3.2 \cdot 10^{19} \cdot I \cdot B} \qquad (1)$$

Where I = *d-c* current in noise diode
B = Bandwidth in cycles

Using a power ratio:

$$M = \frac{\text{noise power output, diode on}}{\text{noise power output, diode off}} = 2$$

A *d-c* current meter in the plate circuit of the noise diode can be calibrated in *db* noise figure:

$$NF = 10 \log 19.4 \cdot I \cdot R_g \qquad (T_o = 25°C) \qquad (2)$$

Where R_g = Source Resistance in ohms.

In general

$$NF = 10 \log \frac{19.4 \cdot I \cdot R_g}{M - 1} \qquad (3)$$

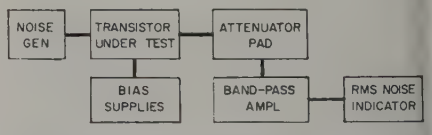


Fig. 66.3—Block diagram of noise test set.

APPLICATIONS ENGINEERING DIGEST NO. 67

Circle No. 200 on Reader Service Card

A Comparison of MADT and Germanium Mesa Switching Transistors; Sprague Electric Co., North Adams, Mass.

This article compares the MADT with the new mesa devices, both from the standpoint of device design and from the standpoint of circuit performance.

In the cross-section of the mesa structure, shown in *Fig. 67.1*, it will be noted that the base and emitter junction and contacts are made side by side and the collector junction area is controlled by the size of both the base and emitter. Note also the considerable amount of germanium located between the actual collector lead and the collector junction. In order to achieve high-frequency performance with this device, the evaporated gold stripe, which forms the base ohmic contact, and the evaporated aluminum stripe, which forms the emitter junction, must be made quite small. This means that the fine wires bonded to these junctions must also be quite small. The base ohmic contact and the emitter junction most both be, of necessity, located on the same sheet resistivity. Therefore, the device design must be compromised. It is desirable to have low resistivity to maintain low base resistance. On the contrary, it is desirable to maintain a high resistance at the emitter junction in order to achieve reasonable emitter breakdown voltage and satisfactory emitter injection efficiency.

In the MADT structure, it is not necessary to make the collector any larger than the actual emitter junction. The compromise between sheet resistivity, to give low base resistance, and sheet resistivity, to give satisfactory emitter injection efficiency, is not necessary. Referring now to *Fig. 67.2*, it can be seen that the low resistance surface forms a ring base contact completely

around the emitter. The base lead, however, can be made remote to the emitter junction since the surface resistivity is very low. It is also apparent that the electrical connection to the collector junction is made right at the collector junction without a large block of germanium in series with the collector junction. The elimination of these parasitic elements means that in well-designed circuits, the MADT will be more stable and show better electrical performance than the mesa structure.

Applications of High Frequency Transistors

The usefulness of any communication system can be summed up in its overload capacitance versus noise figure. In other words, how well can the system tolerate a signal which is much too strong; and, how sensitive is the system. That is, how well can it pick up very weak signals. These two extremes are determined by the automatic gain control of the system. Automatic gain control is essentially a feedback mechanism. Good circuit design dictates that it is better to use voltage feedback control on a high impedance output device. Referring to *Fig. 67.3,* one can see that a plot of overload level versus voltage for the MADT and mesa shows that the MADT is much more linear than the mesa.

The MADT has an edge on the mesa in regard to noise figure. In general, it has been found that the MADT has about 1 *db* less noise than the mesa. Experimental MADT's have been made for use in TV tuners with noise figures lower than tubes.

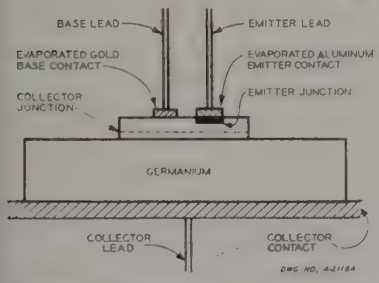


Fig. 67.1—Cross-section of mesa structure.

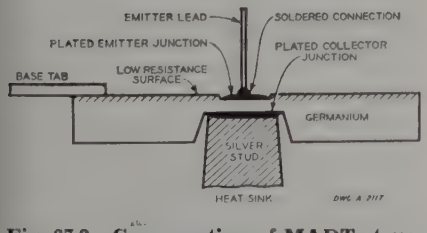


Fig. 67.2—Cross-section of MADT structure.

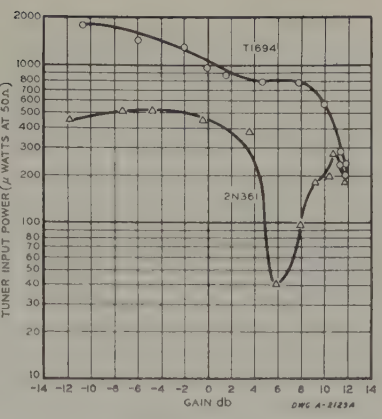


Fig. 67.3—Overload vs. gain for 213 mc amplifier.

Another consideration in the design of high frequency circuits is the output capacitance of the active element. Output capacitance, C_{ob}, is relatively high for the mesa. This complicates circuit design by requiring the addition of neutralizing circuits. In the MADT on the other hand, C_{ob} is so closely controlled that no adjustment of neutralization capacitors is needed and the manufacture of communications equipment is simplified.

Switching Characteristics and Usage

There are two types of transistor switching circuits which are quite popular; the saturated type and the non-saturated type. At best, the non-saturated circuitry is only about twice as fast as the saturated circuitry and has the added disadvantage of dissipating more power and placing much more stringent requirements on the circuit design. The newer types of MADT transistors, however, will switch in saturated circuitry at speeds that exceed present non-saturated circuitry. It will soon be possible to build saturated circuitry computers with switching speeds or repetition rates in excess of 100 *mc*. The ambient temperature in non-saturated systems may run as much as 40 C higher than that of a saturated system. This means that the heat being dissipated by the transistor is two or three times greater in the non-saturated system than in a saturated system. Since it is generally accepted that the device failure rate is a function of temperature, saturated circuit systems should be more reliable than the non-saturated systems. Therefore, a transistor such as the mesa, with a power-handling capability of 150 *mw*, actually is equivalent to a 50 *mw* MADT since, in actual use, nearly three times as much power must be dissipated to successfully use the mesa structure.

The most severe limiting switching characteristic in saturated circuitry is hole storage time. In testing mesa types against the standard 2N501 MADT in both mesa and MADT switching characteristic in saturated circuitry is faster than the mesa in both cases.

The saturation voltage, V_{CE}, is also of great importance in saturated circuitry. *Fig. 67.4* shows a large increase in V_{CE} of the mesa at high current levels. This causes a higher device power dissipation and much less control of output levels.

The gain characteristic of the MADT versus current is constant over a very large range. (See *Fig. 67.5.*) The current gain of the mesa structure is a continuous function of the collector current. As the trend in switching design is toward lower current levels, primarily for power consideration, the ability of the MADT to hold up in gain at low current levels is very desirable. Also, the gain characteristic of the MADT as a function of temperature is nearly constant, whereas the gain of the mesa structure increases very substantially with temperature.

Reliability

The MADT is designed to meet with ease all of the stringent military requirements of MIL-T-19500A.

Although extensive life test data is not available, it has been shown by past experience in conservatively designed computers that the failure rate of the early very low powered 10 *mw* SBT's was about .02% for 1,000 hours. The 85 C storage failure rate for the same units was 2% per 1,000 hours. MADT's stored at 125 C showed only 1 failure in 300 units in 1,000 hours. Using the extrapolated figures derived from this field experience, it appears that the failure rate of the newer MADT's should be in the order of .006% at 40 C.

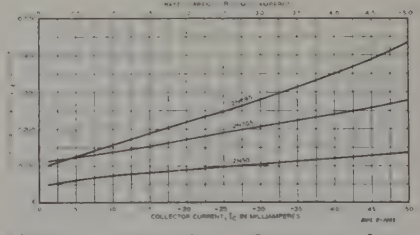


Fig. 67.4—Saturation voltage as a function of collector current.

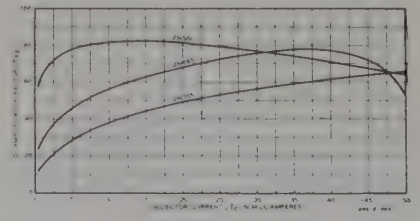


Fig. 67.5—Beta vs. collector current.

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Mar. 24, 1959 to Apr. 28, 1959. In subsequent issues, patents issued from Apr. 28, 1959 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

MARCH 24, 1959

2,879,189 Method For Growing Junction Semiconductive Devices—W. Shockley. Assignee: None. Rate growing techniques are used to produce junction devices from a homogeneous melt.

2,879,190 Fabrication of Silicon Devices—R. A. Logan, A. J. Peters, M. Tanenbaum. Assignee: BTL. Methods of making p-n-p and p-n-i-p silicon devices by a double diffusion technique.

2,879,344 Semiconductor Signal Translating Circuit of Variable Gain—E. Chatterton. Assignee: Philco Corp. An amplifier having a bandwidth insensitive to variations in the a-g-c voltage applied to the transistors thereof.

2,879,405 Semiconductor Photo-Electric Devices—J. I. Pankove. Assignee: RCA. Means for producing an electrical output which is a known function of a light beam position with respect to a photoconductive device.

2,879,409 Diode Amplifier—A. W. Holt. Assignee: USA (Dept. of Commerce). The reverse transient response of a semiconductor diode is employed to produce amplification in a two element rectifying device.

2,879,410 Electric Circuits Including Transistor Devices—H. W. Loeb. Assignee: Automatic Telephone and Electric Co. Ltd. (England). A circuit in which a junction transistor forms a part of the output load impedance of an electron tube.

2,879,411 "NOT AND" Gate Circuits—A. H. Faulkner. Assignee: General Telephone Laboratories Inc. A switching circuit.

2,870,412 Zener Diode Cross Coupled Bistable Triggered Circuit. H. H. Hoge, D. L. Spotten. A circuit which requires a single source of supply voltage.

2,879,457 Ohmic Semiconductor Contact—S. P. Wolsky. Assignee: Raytheon Manufacturing Co. A strong connection is made to a silicon body by using a lead-indium alloying material.

2,879,480 Frequency Modulating Transistor Circuits—D. E. Reed. Assignee: Western Electric Co. Inc. Sound induced changes in the collector to base impedance of a transistor cause a change in the frequency of the r-f oscillator of the circuit described.

2,897,482 Semiconductor Mixing Circuits—V. P. Mathis, J. J. Suran. Assignee: General Electric Co. A converter circuit which provides a modulation product frequency produced by mixing an externally applied signal and a locally generated signal.

March 31, 1959

2,880,117 Method of Manufacturing Semiconducting Materials—J. M. Hanlet. Assignee: Societe d'Electronique et d'Automatisme (France). A method in which silicon is deposited on a heated metal plate in an atmosphere containing hydrogen and silicon tetrachloride.

2,880,312 Transistor Oscillator-Mixer With Received and Local Oscillations Applied Between Emitter and Base—R. C. Koch. Assignee: I. D. E. A. An i-f signal-producing circuit.

2,880,330 Non-Saturating Transistor Trigger Circuits—J. G. Linvill, R. L. Wallace Jr. Assignee: BTL. A circuit in which the transistors continuously remain in the operating state.

2,880,331 Time Controlled Signal Discriminator Circuit—O. L. MacSorley. Assignee: IBM. A circuit for signal discrimination based on a pre-established signal time code.

2,880,332 Transistor Flip-Flop Circuit—C. L. Wanlass. Assignee: North American Aviation. A charge across a capacitor represents the state of the circuit, said charge being regenerated at each clock pulse.

April 7, 1959

2,881,103 Manufacture of Semiconductor Devices—D. J. Brand, J. Ewels. Assignee: The General Electric Co. Electrode manufacturing technique involving the use of a silicon-tin-aluminum alloy to form a silicon-aluminum layer on the semiconductor surface.

2,881,267 Cascaded Transistor and Vacuum Tube Amplifier—H. van de Weg. Assignee: North American Philips Co. Inc. A low distortion amplifier circuit.

2,881,269 High Impedance Transistor Circuits—R. A. Hanel, R. S. Stampfl. Assignee: USA (Dept of the Army). A circuit arrangement which prevents normal base-collector fields from forming thus preventing signal current flow, and thereby providing high collector impedance.

2,881,310 Frequency Compensation for Gain Controlled Transistor Converter Circuit—D. D. Holmes Assignee: RCA. Capacity variations applied to the oscillator portion of the circuit compensate for transistor input capacity variations as a-g-c is applied to the device.

2,881,332 Control Apparatus—J. L. Jensen. Assignee: Minneapolis-Honeywell. A two-channel modulator for converting d-c to a-c, said conversion taking place in a channel determined by the polarity of the d-c signal.

2,881,333 Transistorized Counter—R. H. Pickard. Assignee: USA (Navy Dept.). A pulse counter circuit using two transistorized bistable multivibrators has an adjustable scale of count of four or more.

2,881,369 Glass Sealed Crystal Rectifier—J. N. Carman Jr. Assignee: Pacific Semiconductors. A hermetically sealed crystal rectifier assembly employing a glass cylindrical crystal housing subassembly sealed at both ends with Kovar shells.

2,881,370 Manufacture of Semiconductor Devices—I. D. Colson. Assignee: General Electric Co. Ltd. A semiconductor metallic housing assembly configuration which promotes effective cooling of the device.

April 14, 1959

2,882,192 Semiconducting Materials and Devices Made Therefrom—J. H. Wernick. Assignee: BTL. Devices are made from Cu_3AsS_4 and Cu_3SbS_4, which materials possess both intrinsic and extrinsic semiconducting properties.

2,882,193 Semiconducting Materials and Devices Made Therefrom—J. H. Wernick. Assignee: BTL. P-N junction devices having intrinsic energy gaps of 0.8 to 2 ev are made by addition of impurities from Group VII to the substances Cu_3SbS_3, Ag_3AsS_3, Cu_3AsS_3.

2,882,194 Semiconducting Materials and Devices Made Therefrom—J. H. Wernick. Assignee: BTL. Means of producing p-n junction devices by addition of iodine to the substances $CuSbS_2$, $AgBiS_2$.

2,882,195 Semiconducting Materials and Devices Made Therefrom—J. H. Wernick. Assignee: BTL. P-N junction devices having intrinsic energy gaps of 0.7 to 0.9 ev are produced by introducing group VII impurities into the substances, $CuPbSbS_3$, $CuPbAsS_3$, $CuPbBiS_3$.

2,885,345 Register For A Telephone System—A. H. Faulkner. Assignee: General

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

Telephone Laboratories. A transistorized pulse counter and register, counts and registers the count on a binary basis.

2,882,350 Complementary Transistor AGC System—A. P. Stern, J. A. Raper. Assignee: General Electric Co. A system, the output amplitude of which is independent of fluctuations of the supply voltage.

2,882,353 Series Parallel Transistor Circuits—N. Freedman. Assignee: Raytheon Manufacturing System. An amplifier circuit arrangement which provides direct cascading of amplifier stages and which eliminates the need for impedance matching means between successive stages.

2,882,402 Transistor Oscillator—A. T. Ireland. Assignee: USA (Dept of the Army). In an audio oscillator, the polarity of an applied d-c input signal determines which one of a pair of transistors will function as such and which one will act as a low value resistor in a feedback circuit.

2,882,424 Ring Circuit—L. E. Wohr. Assignee: IBM. A transistorized ring circuit of the Leslie type wherein separate inputs are provided for the odd and even stages.

2,882,450 Automatic Illuminating Control Unit—O. J. McCabe. Assignee: Superior Electric Co. In a system for maintaining a constant level of illumination, a detecting device having high light sensitivity at both ends of the visible spectrum.

2,882,462 Semiconductor Device—C. H. Zierdt. Assignee: General Electric Co. Means for producing a hermetically sealed housing for a semiconductor device.

2,882,463 MultiCollector Transistor Providing Different Output Impedances and Methods of Producing Same—A. H. Dickinson. Assignee: IBM. A device having at least two collector electrodes, one of which contains a donor type material and which manifests a low output impedance.

2,882,464 Transistor Assemblies—M. E. Blais. Assignee: Raytheon Manufacturing Co. Method of manufacturing a compact tubular shaped p-n-p or n-p-n transistor.

2,882,465 Transistor—J. R. MacDonald. Assignee: Texas Instruments Inc. A multiple base annular shaped transistor device suitable for use as a high frequency amplifier, power amplifier, or modulator, depending on bias arrangements.

2,882,466 Broad Band Microwave Point Contact Rectifier—C. E. Weaver, J. G. Hambor. Assignee: Gahagan Inc. A device operable in the frequency range 100 mc to 10,000 mc.

2,882,467 Semiconducting Materials and Devices Made Therefrom—J. H. Wernick. Assignee: BTL. Semiconducting materials having a range of intrinsic energy gap of 0.6 to 1.0 ev comprising the substances $AgSbSe_2$, $AgBiSe_2$, $AgAsSe_2$ and methods of production thereof.

2,882,468 Semiconducting Materials and Devices Made Therefrom—J. H. Wernick. Assignee: BTL. Semiconducting Materials having a range of intrinsic energy gap of 0.3 to 0.8 ev comprising the substances $AgSbTe_2$, $AgBiTe_2$, $AgAsTe_2$, and methods of manufacture thereof.

2,882,469 Semiconducting Materials and Devices Made Therefrom—J. H. Wernick. Assignee: BTL. Semiconducting materials having a range of intrinsic energy gap of 0.2 to 0.8 ev comprising the substances $CuSbSe_2$, $CuAsS_2$, $CuAsSe_2$, devices made therefrom and methods of production.

2,882,470 Semiconducting Materials and Devices Made Therefrom—J. H. Wernick. Assignee: BTL. A semiconducting compound of Cu_3SbSe_4 having an intrinsic energy gap of 0.2 ev and a point contact device made therefrom.

2,882,471 Semiconducting Materials and Devices Made Therefrom—J. H. Wernick. Assignee: BTL. A semiconducting compound of $AgAsSe_2$ having an energy gap of 0.4 ev, and point contact and junction devices made therefrom.

2,882,514 Electric Circuit Connector—H. K. Krantz. Assignee: BTL. A socket assembly suitable for use with transistor units having pin type contactors.

April 21, 1959

2,883,108 Electronic Counter—R. D. Thornton. Assignee: United-Carr Fastener Corp. A transistorized device for counting objects or shaft revolutions.

2,883,269 Production of Elemental Silicon —I. J. Krchma, C. M. Olson. Assignee: E. I. du Pont de Nemours & Co. A vapor reduction method for producing elemental silicon from a vapor of silicon halide containing trace impurities of zinc or cadmium.

2,883,313 Semiconductor Devices—J. I. Pankove. Assignee: RCA. A multielectrode semiconductor device which operates with input injection of both electrons and holes, and can be employed in cascade arrangement without separate bias thereof.

2,883,454 Signalling Systems—G. C. Sziklai, R. D. Lobman. Assignee: RCA. In a television receiver, a single transistor circuit which performs the functions of d-c reinsertion, sync separation, and sync amplification.

2,883,459 Carrier-Current Intercommunication System—Y. Roy. Assignee: None. A transceiver arrangement which impresses an r-f carrier on the electric power line of the system, employs capacitive coupling of the rectifying circuit to the amplifying and reproducing circuit.

2,883,463 Telephone Pay Station—W. D. Goodale Jr., W. Pferd. Assignee: BTL. In a telephone system a transistorized coin collector mechanism control circuit.

2,883,473 Transistor Gating Circuit—B. McDermott. Assignee: BTL. A circuit which confines a voice-frequency signalling current to a limited transmission path in a transmission system.

2,833,474 Transistor Gating Circuit—W. F. Fritschi. Assignee: BTL. A circuit which assists in preventing leakage of voice frequency signalling current into the voice frequency transmission path.

2,833,479 Class B Amplifier Biasing Circuit —A. I. Aronson. Assignee: RCA. A class AB or class B signal amplifier employing d-c feedback to provide stable and low distortion transistor operation with loss of gain or power.

2,883,539 Transverter—G. Bruck, W. Harter, S. C. Vandoch. Assignee: Avco Mfg. Corp. A d-c to a-c to d-c converter for changing d-c voltage levels.

2,883,544 Transistor Manufacture—P. Robinson. Assignee: Sprague Electric Co. An electron beam directed against a semiconductor forms a cavity therein by generating sufficient heat to volatilize the material in the target area, and which generates x-rays the intensity of which provides a measure of cavity depth.

2,883,562 Circuit For Producing Timing Control Signals—R. E. Graham, E. R. Kretmer. Assignee: BTL. A transistorized clock circuit.

2,883,591 Semiconductor Rectifier Device— H. R. Camp. Assignee: Westinghouse Electric Corp. A liquid-to-vapor self-contained heat exchange system for cooling semiconductor devices.

2,883,592 Encapulated Selenium Rectifiers —L. W. Burton, J. R. Thurell Jr. Assignee: General Electric Co. A method of encapsulating a selenium rectifier in an organic thermosetting casting resin.

April 28, 1959

2,884,544 Electrical Circuits Employing Semiconductor Devices—J. T. Warnock. Assignee: Philco Corp. Semiconductor pulse producing circuits.

2,884,545 Transistor Protection Circuit— G. B. Houck Jr. Assignee: General Precision Laboratory Inc. A circuit arrangement which provides transistor circuits with protection against high reversed current voltages.

2,884,546 Electronic Single-Pole Multithrow Switch—R. W. Emery, R. A. Henle, J. C. Logue. Assignee: IBM. A circuit capable of providing a signal at anyone of a number of output terminals upon application of an appropriate input signal.

2,884,607 Semiconductor Nonlinear Capacitance Diode—A. Uhlir Jr. Assignee: BTL. A semiconductor p-n junction diode which exhibits nonlinear capacitive response at high frequencies and high power levels.

2,885,149 Transistor Rull Adder—G. L. Clapper. Assignee: IBM. A transistor binary full adder which is operable in a series or parallel arrangement.

2,885,309 Method of Tempering Selenium Layers For Selenium Rectifiers and Product—F. Brunke. Assignee: Licentia Patent—Verwaltungs GBMH (Germany). Means of converting crystalline Selenium II to another allotropic crystalline form, Selenium III, which has more desirable electrical properties.

2,885,364 Method of Treating Semiconducting Materials for Electrical Devices— A. I. Swartz. Assignee: Columbia Broadcasting System Inc. Purification and adjustment of electrical properties of silicon is accomplished by treatment with aluminum in an inert atmosphere.

2,885,478 Loudspeaking Telephone Employing Transistors—G. F. Cerofolini. Assignee: General Telephone Laboratories Inc. A loudspeaker and amplifier system built into the telephone subset with provision for simplified control based on the position of the hand set.

(To be Continued)

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High-Performance Diode Logic Circuits Using Lifetime Controlled Transistors and Diodes	Elecl Design News Dec 1960	Description of a conventional diode-transistor NOR logic element design to possess 40 μsec delays per logic function and high reliability by eliminating clamps, speed-up capacitors and high power consumption.	D. E. Farina
Matching a Given Load to a Transistor Class 'B' Stage	Elecl Design News Dec 1960	Four different sets of design equations are derived for the problem of maximum power transfer from a class "B" transistorized stage to a resistive-load.	S. Bernstein-Bever
The Diffused-Base Transistor as an Oscillator. Part 2	Elecl Design News Dec 1960	In Part 1, the equivalent circuit was introduced. All parameters discussed in Part 3 will refer to this equivalent circuit. Definitions of the parameters in this equivalent circuit are given here.	C. D. Simmons
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Thermal and Optical Behaviour of Photo-Transistors	Elecnc Engg (Br) Dec 1960	The thermal and optical characteristics of two photo-transistors have been investigated in order to facilitate the design of photo-heads for use under heavy industrial conditions.	D Shaw B. Crump
Stabilized Voltage Supplies Using Transistors	Elecnc Engg Dec 1960	Two methods of obtaining ±300V stabilized supplies from a common low voltage source are described.	J. S. Bell P. G. Wright
Instrumentation Wide-band Magnetic Tape Recording	Elecnc Engg Dec 1960	Development of an Ampex instrumentation wideband magnetic tape recorder from the "Videotape" TV recorder.	J. P. Pritchard
Read-Out Systems for Transistor Scalers	Elecnc Engg Dec 1960	Three types of read-out display using a meter movement, filament lamp, and neon lamps, are considered for use with the transistor operated scalars.	T. B. Benbow
Switching Transistors	Elecnc Technology Dec 1960	The various methods used for predicting the performance of switching transistors and their validity under conditions of large collector currents is discussed.	J. N. Barry
Laminar Junction Layers New Concept in Microcircuits	Electronics Dec 2, 1960	Silicon semiconductor devices can be formed by vapor deposition of single-crystal layers on single-crystal silicon substrate. Technique is applicable to formation of complete circuits.	J. E. Allegretti D. J. Shombert
Designing Shunt-Peaked Transistor Amplifiers	Electronics Dec 2, 1960	Equations for maximally flat magnitude design and simpler pole-zero cancellation design are presented. Examples and circuits clarify design steps.	R. S. Pepper D. O. Pederson
Solid-State Pulser Drives Chemical Pump	Electronics Dec 2, 1960	Silicon-controlled rectifiers in flip flop circuit replace thyratron power supply in long life and high reliability apparatus application.	U. L. Upson
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Magnetic Tape Recorder Programs Engine Dynamometer Tests	Electronics Dec 16, 1960	Engine parameters are recorded by a transistorized circuit while an automobile undergoes road tests.	V. C. Vanderbilt Jr. C. L. Zimmer
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Microcircuit Binary Full Adder Uses Unipolar Transistors	Electronics Dec 23, 1960	This article describes a microcircuit binary full adder that uses unipolar field effect transistors as its active and passive elements.	M. E. Szekely J. T. Wallmark S. M. Marcus
Orientation of Solar Instruments in Space	Electronics Dec 23, 1960	The azimuth servo system is composed of two separate input systems: the eye system (an array of photo-detectors) and the rate gyro.	C. H. Reynolds M. Reisbeck R. E. Hathaway
Survey of Power Transistors	Electro-Technology Dec 1960	As a guide to what is currently available the editors have assembled (from material furnished by manufacturers) a list of these devices.	J. R. Riggs
Semiconductor Electronics 3-Junction Transistors	Electro-Technology Dec 1960	Energy level diagrams are used to develop the current equations which define the operation of junction transistors.	A. A. Sorenson
A Diode Amplitude Limiter	Insts Exp Tech Pr i Tekh Eksp (tr)	A semiconductor diode unit is described which is designed to reduce insensitive-period-time caused by grid-circuit capacitor charge in tube circuit instruments.	I. A. Radkevitch N. S. Resvyakov V. V. Sokolovskii
A Circuit for Oscillographing the Volt-Ampere Characteristic of a Photodiode	Insts Exp Tech Pr i Tekh Eksp (tr) Dec 1960	A simple circuit is described which uses one electromagnetic switch for obtaining the V-A characteristics and the coordinate axes jointly.	B. V. Tsarenkov
Measuring the Resistance of Semiconductors at High Frequencies	Insts Exp Tech Pr i Tekh Eksp (tr) Dec 1960	A simple method of measuring the resistance of semiconductors at high frequencies by means of an ordinary Q-meter is described.	V. G. Sidyakin E. T. Skorik
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Stabilizers of Weak Currents	Inst Exp Tech Pr i Tekh Eksp (tr) Dec 1960	Several laboratory type current stabilizer circuits of 0.1-11 ma are described. The stabilizers use photocompensated amplifiers and standard cells. The accuracy of stabilization is about 10^{-5}.	A. N. Vetchinkin
An Apparatus for Automatically Recording a Number of Impulses at Low Repetition Rates	Inst Exp Tech Pr i Tekh Eksp (tr) Dec 1960	A transistorized apparatus is described which can operate at indefinitely low frequencies, and which automatically records the number of pulses received during an arbitrary time interval.	A. M. Netsetskii O. I. Sumbaev
Photo Emission and Related Properties of the Alkali-Antimonides	JL Appl Phys Dec 1960	The photo emissive process is discussed and values for the band gaps and electron affinities are presented.	W. E. Spicer
Measurement of Thermal Conductivity by Utilization of the Peltier Effect II—Correction for Wire Radiation and Determination of Specimen Radiation Emissivity	JL Appl Phys Dec 1960	Radiation emissivity of a semiconductor specimen can be calculated from measured temperatures.	R. Simon R. T. Bate E. H. Lougher
Mechanism of Photoconductivity in Micro Crystalline Powders	JL Appl Phys Dec 1960	Four regions having different current voltage characteristics are observed in CdS powder cells upon application of various voltage levels thereto.	R. H. Bube
Field Effect Modulation of Photoconductance in a Quasi Intrinsic Semiconductor	JL Appl Phys Dec 1960	An analysis is made of equilibrium space charge density and the effect thereof on the terminal characteristics of a photo conductive field-effect transistor.	R. R. Bockemuehl
Uniform Avalanche Effect in Silicon Three-Layer Diodes	JL Appl Phys Dec 1960	Current gain and avalanche multiplication interaction in three-layer diodes is employed to produce uniform avalanche effect.	A. Goetzberger
Gold Induced Climb of Dislocations in Silicon	JL Appl Phys Dec 1960	When gold is diffused into silicon at high temperatures, right handed silices are formed from left handed screw dislocations.	W. C. Dash
Thermoelectric and Crystallographic Properties of Ag_2Se	JL Electrochem Soc Dec 1960	Silver selenide has been prepared by fusion techniques and found to be a good thermoelectric material. The Seebeck coefficient, resistivity, and thermal conductivity have been measured as a function of temperature.	J. B. Conn R. C. Taylor
Separation of Sulfur, Selenium, and Tellurium from Arsenic	JL Electrochem Soc Dec 1960	Three methods have been investigated for separating trace amounts of sulfur present in high-purity arsenic. These are: (a) vacuum sublimation, (b) sublimation in a hydrogen stream, and (c) distillation of arsenic from an arsenic-lead solution.	J. M. Whelan J. D. Struthers J. A. Ditzenberg
Orientation-Dependent Distribution Coefficients in Melt-Grown InSb Crystals.	JL Phys Chem Solids Dec 1960	During the growth of indium antimonide crystals from the melt, planar crystallographic facets can develop on the solid liquid interface.	J. B. Mullin K. F. Hulme
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Determination of Carrier Mobility and Density in the Surface Layer of a Semiconductor	Sov Phys Solid State Dec 1960	Two Hall Effect methods of measurements are described.	V. K. Subashchiev S. A. Poltinnikov
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Properties of Thermally Induced Conductivity in Single Crystals of CdS	Sov Phys Solid State Dec 1960	The photo sensitivity of crystals is shown to be dependent upon the concentration of local levels in the upper part of the forbidden band.	G. A. Fedorus A. K. Razmadze
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Thermomagnetic Properties of Gallium Antimonide	Sov Phys Solid State Dec 1960	Results of measurements of the Nernst-Ettingshausen effects in p-type germanium are presented.	D. Kh Amirkhanova
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The Optical and Photo Electric Properties of Zinc Selenide and Telluride	Sov Phys Solid State Dec 1960	A determination of physical properties of the substances such as resistivity absorption coefficient, width of forbidden band, luminescence, and others.	G. A. Zholkevich
Anisotropy of Certain Electrical Properties of Single Crystals of Zinc Antimonide	Sov Phys Solid State Dec 1960	The electrical properties of ZnSb are shown to be anisotropic and calculation of a forbidden band width yields a value of 0.6 ev.	M. V. Kot I. V. Kretsu
Vacuum Techniques and Equipment	Sperry Engg Rev Dec 1960	The engineering uses of high vacuum are many. Although freely available in outer space, vacuum must be produced in the laboratory through careful technology. The methods used and the problems encountered are discussed in this paper.	D. Lichtman
Semiconductors and Technical Progress	Technical Transl Dec 13, 1960 Don (USSR)	Order from OTS. Office of Technical Services. Dept. of Commerce, Wash, 25, D.C. $0.50, No. 60-41419.	

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Electroluminescence: New Source of Light	Technical Transl Dec 13, 1960 Soc France des Elec (Fr)	Order from SLA Translation Center. The John Crerar Lib. 86 E. Randolph St., Chi. 1, Ill. $3.80, No. 60-18381.	G. Destriau
Semiconductor Devices and their Applications	Technical Transl Dec 13, 1960 Pol Prib Prim (Rus)	Order from Photoduplication Svc. Pub. Board Prog (LC) Lib Cong. Wash 25, D. C. $57.60, No. 60-23872.	
Concerning the Electroluminescence of Semiconducting Phosphors.	Technical Transl Dec 13, 1960 Zeit Nat (West G)	Available on loan only from SLA No. 6018144	A. Fisher
A Study of Crystal Oscillator Circuits	US Govt Res Repts Dec 11 1960 LC $10.80 PB142865	A design method for a cathode coupled crystal oscillator which operates in the 75 mc to 150 mc range.	H. E. Giuen A. O. Plait
Transistor Circuits Alter Frequency Response of Magnetic Amplifiers	US Govt Res Repts Dec 11 1960 LC $3.30 PB139260	Transistor circuits furnish power for lead or lag characteristics of magnetic amplifiers with negligible effect on gain or drift of said amplifiers.	J. C. Taylor C. L. Wyman
Study of Methods of Cooling Semiconductor Devices	US Govt Res Repts Dec 11 1960 LC $3.30 PB142943	A handbook of currrent methods.	J. P. Welsh
1 MC Silicon Transistor Circuits Applicable to Airborne Digital Systems	US Govt Res Repts Dec 11 1960 LC $6.30 PB139205	Devices for use in digital systems operating in the temperature range—55° to 100° C.	V. V. Sferrino W. G. Schmidt
Design Techniques for Transistor Active Circuits	US Govt Res Repts Dec 11 1960 LC $3.30 PB138888	A medium frequency high Q band pass filter using transistor negative feedback to increase Q.	Microwave Res Inst.
Optimum Synthesis of Active Band-Pass Filters	US Govt Res Repts Dec 11 1960 LC $10.80 PB139155	Design techniques for synthesis of band pass filters.	Microwave Res Inst. Poly Tech Inst of Bklyn
Development of Miniature Facsimile Scanning Head Employing Transistors	US Govt Res Repts Dec 11 1960 LC $9.30 PB142807	A scanning head using a transistor modulator circuit and a two stage transistor amplifier.	K. H. Beck
Transistor Crystal-Controlled Oscillator Study	US Govt Res Repts Dec 11 1960 LC $6.30 PB139058	Progress report on studies in this area.	W. McSpadden D. E. Reed
Transistor Crystal Oscillator Circuitry	US Govt Res Repts Dec 11 1960 LC $13.80 PB139055	Circuit evaluation and transistor parameter tests are conducted.	W. Mc Spadden R. J. Shedko W. J. Tobin
Transistor Crystal Oscillator Circuitry	US Govt Res Repts Dec 11 1960 LC $9.30 PB139056	Two sets of design data sheets are developed based on power relationships in a feedback oscillator, and negative resistance analysis of a Pierce oscillator.	W. McSpadden R. J. Shedko W. T. Tobin
Intrinsic Barrier Transistor Techniques	US Govt Res Rpts Dec 11 1960 LC $18.30 PB138663	Techniques of producing intrinsic barrier transistors, particularly coaxial transistors.	J. L. Buie M. A. Clark
Variable Capacitor Diodes	US Govt Res Repts Dec 11 1960 LC $15.30 PB142871	Design theory for electronic tuning type p-n-p-n variable capacitance diodes.	H. D. Frazier
Diffused Semiconductor Device No. 19	US Govt Res Repts Dec 11 1960 LC $12.30 PB138771	Design, fabrication, and performance of a grown-diffused silicon triode transistor.	T. S. Edwards
Diffused Semiconductor Device No. 23	US Govt Res Repts Dec 11 1960 LC $9.30 PB138772	Means for mass producing a transistor device.	W. C. Brower et al
The Metallography of Indium Antimonide	US Govt Res Repts Dec 11 1960 LC $3.30 PB138717	The dislocation etch pit arrays in polycrystalline and single-crystal InSb are discussed.	R. E. Maringer J. J. Duga
The Germanium CuK²(222) Double X-Ray Reflections. I—Indexation	US Govt Res Repts Dec 11 1960 LC $3.30 PB143013	A method of calculating azimuthal positions of double x-ray reflection points.	E. Alexander B. S. Fraenkel Z. H. Dalmen
Properties of Sulphide Semiconductors	US Govt Res Repts Dec 11 1960 LC $3.30 PB138736	A study of As_2Te_3 and Sb_2Se_3	J. W. Buttrey
Measurements of Bulk Lifetime in Silicon	US Govt Res Repts Dec 11 1960 LC $6.30 PB138724	A discussion of the use of the photomagnetoelectric effect to measure lifetime in p-type silicon.	R. W. Beck C. S. Peet A. C. Beer
Investigations of Surface Properties of Silicon and other Semiconductors	US Govt Res Repts Dec 11 1960 LC $1.80 PB138190	Results of low energy electron diffraction experiments on the (111) face of a silicon crystal are discussed.	R. E. Farnsworth J. A. Dillon Jr. R. E. Schlier
Investigations of Surface Properties of Silicon and Other Semiconductors	US Govt Res Repts Dec 11 1960 LC $4.80 PB138858	Lattice structure and gas adsorption of silicon and silicon carbide is studied.	H. E. Farnsworth J. A. Dillon Jr. R. E. Schlier
Investigations of Surface Properties of Silicon and Other Semiconductors	US Govt Res Repts Dec 11 1960 LC $3.30 PB138812	Low energy electron diffraction methods are used to study atomic arrangement for InSb and adsorption characteristics for oxygen.	H. E. Farnsworth D. Haneman
Investigations of Surface Properties of Silicon and Other Semiconductors	US Govt Res Repts Dec 11 1960 LC $3.30 PB142810	Sharp diffraction patterns from a (111) InSb surface are obtained after ion bombardment and annealing treatments.	H. E. Farnsworth D. Haneman
Research Directed Toward the Investigation of Silicon and Silicon Carbide Surfaces	US Govt Res Repts Dec 11 1960 LC $3.30 PB138725	The role of the ambient pressure in thermal etching is studied.	J. A. Dillon Jr.
Research in Physical Chemistry and Metallurgy of Semiconducting Materials	US Govt Res Repts Dec 11 1960 LC $6.30 PB138834	Vapor phase deposition of silicon on tantalum is discussed.	K. E. Bean W. E. Medcalf
Research in Physical Chemistry and Metallurgy of Semiconducting Materials	US Govt Res Repts Dec 11 1960 LC $4.90 PB138835	Methods of preparation of boron tribromide and deposition of elemental boron.	K. E. Bean R. J. Starks W. E. Medcalf

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

MANUFACTURERS

AEG—	Allgemeine Elekticitats-Gesellschaft
ASC—	American Semiconductor Corp.
AMP—	Amperex Electronic Corp.
AEI—	Associated Electrical Industries, Ltd.
BEN—	Bendix Corp.
BER—	Berkshire Corp.
BOM—	Bomac Labs
BRA—	Bradley Semiconductor Corp.
BRI—	Britton Electronics Corp.
CBS—	CBS Electronics
CDC—	Continental Device Corp.
CDLF—	Compagnie des Lampes
COD—	Computer Diode Corp.
COL—	Columbus Electronics Corp.
CON—	Controls Co., of America
CTP—	Clevite Transistor Products, Inc.
CSF—	(Cosem) Cie Generale des Semi-Conducteurs
DEL—	Delco Radio
DES—	Delta Semiconductors, Inc.
DIC—	Dickson Electronics Corp.
EEVB—	English Electric Valve Co., Ltd.
ERI—	Erie Resistor Corp.
ESP—	Espey Mfg. and Electronics Corp.
FAN—	Fansteel Metallurgical Corp.
FERB—	Ferranti Ltd.
FSC—	Fairchild Semiconductor Corp.
GAH—	Gahagan, Inc.
GECB—	General Electric Co., Ltd.
GE—	General Electric Company, Semiconductor Div.
GELC—	Canadian General Electric Co.
GIC—	General Instrument Corp.
HAFO—	Institutet for Halvedarforskning
HITJ—	Hitachi Ltd., Mushashi Works
HUG—	Hughes Products Division
ITC—	Industro Transistor Corp.
IDC—	International Diode Corp.
INRB—	International Rectifier Co., Ltd.
INRC—	International Rectifier Corp.
IRC—	International Resistance Co.
ITT—	International Tel. & Tel. Corp.
KEM—	Kemtron Electron Products, Inc.
KOKJ—	Kobe Kogyo Corp.
MAL—	P. R. Mallory & Co., Inc.
MATJ—	Matushita Electronics Corp.
MIC—	Microwave Associates, Inc.
MISI—	Mistral
MOT—	Motorola, Inc
MUL—	Mullard, Ltd.
NAE—	North American Electronics
NPC—	Nucleonic Products Co., Inc.
OHI—	Ohio Semiconductor Inc.
OHM—	Ohmite Manufacturing Co.
PHI—	Philco Corp. Lansdale Div., Semiconductor Operations
PHIN—	Philips Gloeilampenfabrieken
PLEB—	The Plessey Co.
PRI—	Princeton Electronics Corp.
PSI—	Pacific Semiconductors, Inc.
RADF—	La Radiotechnique Div. Tubes Electroniques
RAY—	Raytheon Company
RCA—	Radio Corporation of America, Semiconductor Div.
RDR—	Radio Development and Research Corp.
RHE—	Rheem Semiconductor Corp.
HSD—	Hoffman Semiconductor Division
ROSG—	Dr. Ing. Rudolph Rost
SAR—	Sarkes Tarzian, Inc., Rectifier Division
SCN—	Semicon, Inc.
SEM—	Semi-Elements Inc.
SIE—	Siemens & Halske Aktiengesellschaft
SIL—	Silicon Transistor Corp.
SGSI—	Societa Generale Semiconduttori
SLA—	Slater Electric Inc.
SOIF—	Societe Industrial de Liaisons
SOD—	Solitron Devices, Inc.
SONY—	Sony Corp.
SSD—	Sperry Semiconductor Division
SSP—	Solid State Products, Inc.
STC—	Shockley Transistor Corp.
STCB—	Standard Telephone & Cables, Ltd.
STCA—	Standard Tel. and Cables Pty, Ltd.
SYL—	Sylvania Electric Products, Inc.
SYN—	Syntron Co.
TEX—	Texas Research Assoc.
TFKG—	Telefunken, Ltd.
TI—	Texas Instruments Incorporated
TKD—	Tekade
TRA—	Transitron Electronic Corp.
TUN—	Tung-Sol Electric, Inc.
TSC—	Trans-Sil Corp.
UCI—	United Components
UNI—	Unitrode Transistor Prods., Corp.
USS—	U. S. Semiconductor Products, Inc.
VIC—	Vickers Inc.
WEC—	Western Electric Co.
WEST—	Westinghouse Electric Corp.

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA) (volts) (°C)	MFR. (See code at start of charts)
B205	2	Si	50	50		19 25A	.60	1000 50 125C	SYN-6
B210	2	Si	100	100		19 25A	.60	1000 100 125C	SYN-6
B220	2	Si	200	200		19 25A	.60	1000 200 125C	SYN-6
B230	2	Si	300	300		19 25A	.60	1000 300 125C	SYN-6
B240	2	Si	400	400		19 25A	.60	1000 400 125C	SYN-6
B305	2	Si	50	50		26 25A	.60	1000 50 125C	SYN-6
B310	2	Si	100	100		26 25A	.60	1000 100 125C	SYN-6
B320	2	Si	200	200		26 25A	.60	1000 200 125C	SYN-6
B330	2	Si	300	300		26 25A	.60	1000 300 125C	SYN-6
B340	2	Si	400	400		26 25A	.60	1000 400 125C	SYN-6
B505	2	Si	50	50		45 25A	.60	2000 50 125C	SYN-6
B510	2	Si	100	100		45 25A	.60	2000 100 125C	SYN-6
B520	2	Si	200	200		45 25A	.60	2000 200 125C	SYN-6
B530	2	Si	300	300		45 25A	.60	2000 300 125C	SYN-6
B540	2	Si	400	400		45 25A	.60	2000 400 125C	SYN-6
CS122B	2	Si	200		1300 1.2	1.0 25		750 200 150	TUN
CS122D	2	Si	400		1300 1.2	1.0 25		500 400 150	TUN
CS122F	2	Si	600		1300 1.2	1.0 25		330 600 150	TUN
CS122H	2	Si	800		1300 1.2	1.0 25		250 800 150	TUN
SLA5	1	Si	50	50		50 25C	1.2	1000 50 25A	SLA
SLA10	1	Si	100	100		50 25C	1.2	1000 100 25A	SLA
SLA11	1	Si	50	50		1.0 100A	.60		SLA
SLA12	1	Si	100	100		1.0 100A	.60		SLA
SLA13	1	Si	200	200		1.0 100A	.60		SLA
SLA14	1	Si	300	300		1.0 100A	.60		SLA
SLA15	1	Si	400	400		1.0 100A	.60		SLA
SLA16	1	Si	500	500		1.0 100A	.60		SLA
SLA17	1	Si	600	600		1.0 100A	.60		SLA
SLA18	1	Si	800	800		1.0 100A	.60		SLA
SLA19	1	Si	1000	1000		1.0 100A	.60		SLA
SLA20	1	Si	200	200		50 25C	1.2	1000 200 25A	SLA
SLA30	1	Si	300	300		50 25C	1.2	1000 300 25A	SLA
SLA40	1	Si	400	400		50 25C	1.2	1000 400 25A	SLA
SLA50	1	Si	500	500		50 25C	1.2	1000 500 25A	SLA
SLA60	1	Si	600	600		50 25C	1.2	1000 600 25A	SLA
SLA80	1	Si	800	800		50 25C	1.2	1000 800 25A	SLA

SWITCHING DIODES

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. REVERSE CURRENT @ 25°C I_b (μa) @ E_b (volts)	Recovery Characteristics: TEST CONDITIONS Fwd. I_f (ma) Rev. to E_b (volts)	Z_{rec} @ time (t) (K ohms) (usec)	MFR. (See code at start of charts)
DW120	Si	100	100	400 1.0	.025 75	5.0 6.5	6.5 .004	DES
DW130	Si	100	100	50 1.0	.025 75	5.0 6.5	6.5 .004	DES
MA4121	Si			30 1.0	200 4.0			MIC
MA4245	Si	50		30 1.0	.10 50	10 5.0	5.0 .004	MIC
MA4303	Si	50		10 1.0	.025 40	10 5.0	5.0 .004	MIC
MA4304	Si	50		10 1.0	.025 40	10 5.0	5.0 .004	MIC
MA4305	Si	50		10 1.0	.025 20	10 5.0	5.0 .004	MIC
MA4306	Si	50		10 1.0	.025 20	10 5.0	5.0 .004	MIC
MA4307	Si	100		30 1.0	.050 75	10 5.0	5.0 .004	MIC
MA4308	Si	100		30 1.0	.050 75	10 5.0	5.0 .004	MIC
MA4413	Si	40		10 1.0		10 5.0	5.0 .004	MIC
MA4414	Si	30		10 1.0		10 5.0	5.0 .004	MIC
SPD105	Ge	32	32	10 1.4	220 32	10 14	70 .50	CSF
SP100	Si	75		10 1.0	.10 50	10 6.0	1.0ma .002	GIC
SP101	Si	30		100 1.0	.025 20	10 6.0	1.0ma .002	GIC
SP102	Si	40		100 1.0	.025 30	10 6.0	1.0ma .002	GIC
SP103	Si	50		100 1.0	.025 40	10 6.0	1.0ma .002	GIC
SP104	Si	75		100 1.0	.025 50	10 6.0	1.0ma .002	GIC
SP105	Si	100		100 1.0	.025 75	10 6.0	1.0ma .002	GIC
SP106	Si	125		100 1.0	.025 100	10 6.0	1.0ma .002	GIC
SP200	Si	200		100 1.0	.10 150	30 IR-30ma	1.0ma .050	GIC

CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFICATION	DESCRIPTION	MFR.
TD5	10	Ip/Iv-8.0;Switching Speed-.80mu sec;Ip-20ma	GIC
TD5A	10	Ip/Iv-12;Switching Speed-.80mu sec;Ip-20ma	GIC
TD6	10	Ip/Iv-8.0;Switching Speed-.80mu sec;Ip-10ma	GIC
TD6A	10	Ip/Iv-12;Switching Speed-.80mu sec;Ip-10ma	GIC
TD7	10	Ip/Iv-8.0;Switching Speed-.80mu sec	GIC

SLA442B	1	S1	300	300			.75	50A	1.5	1.0	300	25	SLA
SLA443	1	S1	400	400			.30	50A	1.5	1.5	400	25	SLA
SLA443B	1	S1	400	400			.75	50A	1.5	1.5	400	25	SLA
SLA444	1	S1	500	500			.30	50A	1.5	1.75	500	25	SLA
SLA444B	1	S1	500	500			.65	50A	1.5	1.75	500	25	SLA
SLA445	1	S1	600	600			.30	50A	1.5	2.0	600	25	SLA
SLA445B	1	S1	600	600			.65	50A	1.5	2.0	600	25	SLA
SLA536	1	S1	50	50			.25	150A	.50	400		150	SLA
SLA537	1	S1	100	100			.25	150A	.50	400		150	SLA
SLA538	1	S1	200	200			.25	150A	.50	300		150	SLA
SLA539	1	S1	300	300			.25	150A	.50	300		150	SLA
SLA540	1	S1	400	400			.25	150A	.50	300		150	SLA
SLA547	1	S1	600	600			.25	150A		300		150	SLA
SLA560	1	S1	800	800			.25	100A		300		150	SLA
SLA561	1	S1	1000	1000			.25	100A		300		150	SLA
SLA599	1	S1	50	50	200	1.5	.40	100A	1.5	.025	50	25	SLA
SLA599A	1	S1	50	50	200	1.5	.40	100A	1.5	1.0	50	25	SLA
SLA600	1	S1	100	100	200	1.5	.40	100A	1.5	.025	100	25	SLA
SLA600A	1	S1	100	100	200	1.5	.40	100A	1.5	1.0	100	25	SLA
SLA601	1	S1	150	150	200	1.5	.40	100A	1.5	.025	150	25	SLA
SLA601A	1	S1	150	150	200	1.5	.40	100A	1.5	1.0	150	25	SLA
SLA602	1	S1	200	200	200	1.5	.40	100A	1.5	.025	200	25	SLA
SLA602A	1	S1	200	200	200	1.5	.40	100A	1.5	1.0	200	25	SLA
SLA603	1	S1	300	300	200	1.5	.40	100A	1.5	.025	300	25	SLA
SLA603A	1	S1	300	300	200	1.5	.40	100A	1.5	1.0	300	25	SLA
SLA604	1	S1	400	400	200	1.5	.40	100A	1.5	.025	400	25	SLA
SLA604A	1	S1	400	400	200	1.5	.40	100A	1.5	1.5	400	25	SLA
SLA605	1	S1	500	500	200	1.5	.40	100A	1.5	.025	500	25	SLA
SLA605A	1	S1	500	500	200	1.5	.40	100A	1.5	2.0	500	25	SLA
SLA606	1	S1	600	600	200	1.5	.40	100A	1.5	.025	600	25	SLA
SLA606A	1	S1	600	600	200	1.5	.40	100A	1.5	2.5	600	25	SLA
SLA1095	1	S1	500	500			.25	135A	.50	300		150	SLA
SLA1096	1	S1	600	600			.25	130A	.50	300		150	SLA
SLA1100	1	S1	100	100			.25	150A	1.5	300		150	SLA
SLA1101	1	S1	200	200			.25	150A	1.5	300		150	SLA
SLA1102	1	S1	300	300			.25	150A	1.5	300		150	SLA
SLA1103	1	S1	400	400			.25	150A	1.5	300		150	SLA
SLA1104	1	S1	500	500			.25	150A	1.5	300		150	SLA
SLA1105	1	S1	600	600			.25	150A	1.5	300		150	SLA
SLA1487	1	S1	100	100			.25	125A	.55	400		125	SLA
SLA1488	1	S1	200	200			.25	125A	.55	300		125	SLA
SLA1489	1	S1	300	300			.25	125A	.55	300		125	SLA
SLA1490	1	S1	400	400			.25	125A	.55	300		125	SLA
SLA1491	1	S1	500	500			.25	110A	.55	300		125	SLA
SLA1492	1	S1	600	600			.25	95A	.55	300		125	SLA
SLA1692	1	S1	100	100			.25	100A		500		100	SLA
SLA1693	1	S1	200	200			.25	100A		500		100	SLA
SLA1694	1	S1	300	300			.25	100A		500		100	SLA
SLA1695	1	S1	400	400			.25	100A		500		100	SLA
SLA1696	1	S1	500	500			.25	100A		500		100	SLA
SLA1697	1	S1	600	600			.25	100A		500		100	SLA
SLA2610	1	S1	100	100			.25	150A	.50	10	100	25	SLA
SLA2611	1	S1	200	200			.25	150A	.50	10	200	25	SLA
SLA2612	1	S1	300	300			.25	150A	.50	10	300	25	SLA
SLA2613	1	S1	400	400			.25	150A	.50	10	400	25	SLA
SLA2614	1	S1	500	500			.25	150A	.50	10	500	25	SLA
SLA2615	1	S1	600	600			.25	150A	.50	10	600	25	SLA
SLA2616	1	S1	800	800			.25	150A	.50	10	800	25	SLA
SLA2617	1	S1	1000	1000			.25	150A	.50	10	1000	25	SLA
SLA3193	1	S1	200				.75	25	1.2	10	200	25A	SLA
SLA3194	1	S1	400				.75	25	1.2	10	400	25A	SLA
SLA3195	1	S1	600				.75	25	1.2	10	600	25A	SLA
SLA3196	1	S1	800				.50	25	1.2	10	800	25A	SLA

UNDER USE
1 - General Purpose
2 - Power Rectifier
3 - Magnetic Amplifier
5 - Controlled Rectifier
6 - Dual Rectifier
7 - Controlled Forward Conductance
8 - High Voltage Rectifier
9 - Bridge Rectifier
⍁ - Revised Specifications
Ø - Insulated Base
Δ - Direct Tube Replacement
† - Pair
# - Forced Air Cooling

OTHER
4 - For half wave resistance lead average over 1 cycle

REVERSE CURRENT
⍁ - Dynamic

MFR
6 - Available in Stack form from Mfr.

FOLLOWING ANY TEMPERATURE READING
A - Ambient
C - Case
J - Junction
S - Storage
Δ - Inlet temperature of coolant

2 - Mixer or Detector Diodes
3 - Variable Capacitator Diodes
4 - Photodiodes
5 - Solar Cells
6 - Harmonic Generator Diodes
8 - Controlled Rectifier
9 - PNPN Switching Diode
10 - Tunnel Diode
11 - Photoconductive Cell
M - Other Miscellaneous Types

PREVIOUSLY REGISTERED NEWLY ANNOUNCED DIODES

COSEM:
1N64, 1N81

CLEVITE TRANSISTOR:
1N789, 1N790, 1N791, 1N792, 1N793, 1N794, 1N795, 1N796, 1N797, 1N798, 1N799, 1N800, 1N801, 1N802, 1N803, 1N804, 1N806, 1N807, 1N914, 1N916, 1N925, 1N926, 1N927, 1N928

DELTA SEMICONDUCTORS:
1N3070, 1N3257, 1N3258

GENERAL ELECTRIC:
1N248C, 1N249B, 1N249C, 1N250B, 1N250C, 1N1124, 1N1124A, 1N1125, 1N1126, 1N1126A, 1N1127, 1N1128, 1N1128A, 1N1169, 1N1169A, 1N1191, 1N1192, 1N1193, 1N1194, 1N1195, 1N1195A, 1N1196, 1N1196A, 1N1197, 1N1197A, 1N1198, 1N1198A, 1N1199, 1N1200, 1N1201, 1N1202, 1N1203, 1N1204, 1N1205, 1N1206, 1N1217, 1N1218, 1N1219, 1N1220, 1N1221, 1N1222, 1N1223, 1N1224, 1N1225, 1N1226, 1N1341, 1N1342, 1N1343, 1N1344, 1N1345, 1N1346, 1N1347, 1N1348, 1N1446, 1N1581, 1N1582, 1N1583, 1N1584, 1N1585, 1N1586, 1N1587, 1N1612, 1N1613, 1N1614, 1N1615, 1N1616, 1N1765, 1N1765A, 1N1766, 1N1766A, 1N1767, 1N1767A, 1N1768, 1N1768A, 1N1769, 1N1769A, 1N1770, 1N1770A, 1N1771, 1N1771A, 1N1772, 1N1772A, 1N1773, 1N1773A, 1N1774, 1N1774A, 1N1775, 1N1775A, 1N1776, 1N1776A

GENERAL INSTRUMENT:
1N903, 1N903A, 1N904, 1N904A, 1N905, 1N905A, 1N906, 1N906A, 1N907, 1N907A, 1N908, 1N908A, 1N914, 1N914A, 1N916, 1N916A, 1N2154, 1N2155, 1N2156, 1N2157, 1N2158, 1N2159, 1N2160

P. R. MALLORY:
1N536 thru 1N540, 1N1095, 1N1096, 1N1124, 1N1126, 1N1128, 1N2069, 1N2070, 1N2071

MICROWAVE ASSOCIATES:
1N920, 1N921

MOTOROLA:
1N746A, 1N747A, 1N748A, 1N749A, 1N750A, 1N751A, 1N752A, 1N753A, 1N754A, 1N755A, 1N756A, 1N757A, 1N758A, 1N759A, 1N821, 1N821A, 1N823, 1N823A, 1N825, 1N825A, 1N827, 1N827A

PRINCETON ELECTRONICS:
1N251, 1N440, 1N440B, 1N441, 1N441B, 1N442, 1N442B, 1N443, 1N443B, 1N444, 1N444B, 1N445, 1N445B, 1N456, 1N456A, 1N457, 1N457A, 1N458, 1N458A, 1N459, 1N459A, 1N461, 1N461A, 1N462, 1N462A, 1N463, 1N463A, 1N464, 1N464A, 1N482, 1N482A, 1N482B, 1N483, 1N483A, 1N483B, 1N484, 1N484A, 1N484B, 1N485, 1N485A, 1N485B, 1N486, 1N486A, 1N486B, 1N487, 1N487A, 1N488, 1N488A, 1N625, 1N626, 1N628, 1N629, 1N643, 1N643A, 1N646, 1N648, 1N649, 1N658, 1N659, 1N660, 1N661, 1N662, 1N663, 1N676, 1N677, 1N678, 1N679, 1N681 thru 1N687, 1N689, 1N789 thru 1N804, 1N839, 1N891 thru 1N893, 1N903, 1N908, 1N914, 1N916, 1N925, 1N926, 1N927, 1N928

RAYTHEON:
1N332, 1N333, 1N334, 1N335, 1N336, 1N337, 1N339,1N340,1N341,1N342,1N343,1N344,1N345,1N346, 1N348, 1N349,1N440,1N440B,1N441,1N441B,1N442,1N442B,1N443,1N443B, 1N444, 1N444B, 1N445, 1N445B, 1N550, 1N551, 1N552, 1N553, 1N554, 1N555, 1N599, 1N599A, 1N600, 1N600A, 1N601, 1N601A, 1N602, 1N602A, 1N603, 1N603A, 1N604, 1N604A, 1N605, 1N605A, 1N606, 1N606A, 1N607, 1N607A, 1N608, 1N608A, 1N609, 1N609A, 1N610, 1N610A, 1N611, 1N611A, 1N612, 1N612A, 1N613, 1N613A, 1N614, 1N614A, 1N1100, 1N1101, 1N1102, 1N1103, 1N1104, 1N1105, 1N1115, 1N1116, 1N1117, 1N1118, 1N1119, 1N1120, 1N1487, 1N1488, 1N1489, 1N1490, 1N1491, 1N1492, 1N1692, 1N1693, 1N1694, 1N1695, 1N1696, 1N1697, 1N2847, 1N2848, 1N2849, 1N2850, 1N2851, 1N2852, 1N2858, 1N2859, 1N2860, 1N2861, 1N2862, 1N2863, 1N2864

RCA:
1N1199A, 1N1200A, 1N1202A, 1N1203A, 1N1204A, 1N1205A, 1N1206A

TRANS-SIL:
1N1191, 1N1192, 1N1193, 1N1194, 1N1195, 1N1196, 1N1197, 1N1198

WESTINGHOUSE ELECTRIC:
1N536, 1N537, 1N538, 1N539, 1N540, 1N547, 1N560, 1N561, 1N1095, 1N1096

Industry News . . .

CONFERENCE CALENDAR

The Following July 1961 Meetings Are Scheduled:

July 10-14 Conference on Optical Instruments & Techniques, London, England. Sponsored by the International Commission for Optics.

July 16-21 4th International Conference on Medical Electronics combined with 14th Annual Conference on Electrical Techniques in Medicin & Biology, Waldorf Astoria Hotel, N.Y.C Sponsored by IFME, JECMB, IRE-PGBME For Information: Dr. Herman P. Schwan Moore School of Electrical Engng., Univer sity of Penna., Philadelphia 4, Pa.

RESEARCH AND DEVELOPMENT

A facility for simulating outer space conditions, in which semiconductor materials will be studied, is being built by CBS Laboratories, a division of Columbia Broadcasting System, Inc., at its Research Center in Stamford, Conn. Dr. Peter C. Goldmark, President and Director of Research, announced that CBS Laboratories has been awarded a contract for this study by the U. S. Air Force. Its purpose is to provide the Air Force with recommendations as to which semiconductor materials should be used in various space applications. Dr. Wolfgang W. Gaertner, Vice President, Solid State Research and Development, will direct the program.

"With the instrumentation in space vehicles becoming more complicated and versatile, it is increasingly important to study the effects of space environments on variou types of materials," Dr. Gaertner explained. "Semicon ductors must be investigated intensively because thei characteristics are sometimes strongly affected by man types of radiation which are found in different region of the atmosphere and outer space. In the new space simulation facility, we will be able to expose semiconduc tor materials to radiation ranging from visible, ultraviolet and infrared radiation to high-energy electrons. This ex posure will take place under the vacuum and temperatur conditions prevalent in the upper atmosphere and in oute space. The properties of the material then will be evalu ated to predict their actual performance in space ve hicles."

The rapid strides being made in development of thermoelectric materials has opened a new field for cooling systems based on using these devices according to Albert G. Babeaux, vice president of The Birtcher Corporation. Keeping pace with materials development, the firm has launched a program of R&D in application engineering to provide systems and sub-systems for cooling various electronic systems and components. The company's research and development efforts have been concentrated in the broader aspects of systems applications rather than the thermoelectric cooling devices themselves. Mr. Ba beaux said that the devices constitute a means for a rea breakthrough in solving problems of thermal environment, but that it will now require specialists to analyze methods of heat removal from the concept of entire systems. He believes that "thermal engineering" will be a separate engineering function and in fact calls his R&D staff "thermal engineers."

The industrial division has been engaged for the past 18 years in the design and manufacture of cooling devices for tubes, components and semiconductors.

A cooperative program to develop low cost thermoelectric couples has been initiated by Transitron Electronic Corporation and the American Gas Association. The firm has had a thermoelectrics program under way for 2 years and already has developed a lead telluride of greatly improved strength and optimum thermoelectric parameters. The company states that they have also developed a new bonding process which uses a metallurgically bonded junction which has resulted in significantly increased yields and has made possible the production of a complete couple in one operation.

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New Products

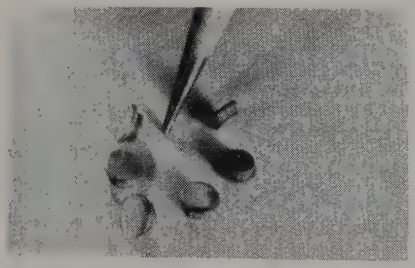
Microcircuit Machine

A new piece of equipment which will complete any microcircuit up to 1.25" square in one continuous operation, from blank to a finished and electrically tested circuit, has been designed to speed research of design engineers, increase output on production lines, and reduce costs of both development and manufacture. Kulicke and Soffa Manufacturing Company, Inc., offers this K&S Model 410 Microcircuit Machine on 90 day delivery. It has been designed so that any microcircuit an engineer can create using the equipment in the research laboratory can be reproduced in quantity with speed and precision using the same equipment in the manufacturing plant.

Circle 100 on Reader Service Card

Miniaturized Tunnel Diodes

Sylvania Electric Products Inc. and General Telephone & Electronics Laboratories Incorporated have announced jointly the development of a miniaturized



tunnel diode, which oscillates at frequencies of 10,000 mc and above. Designated D-4168-D, the 10 kmc, P-type germanium tunnel diode has peak currents of approximately 3.5 ma and minimum peaks to valley ratios of 5:1. Peak current ranges from 4 to 50 ma have also been developed.

Circle 113 on Reader Service Card

Miniature Markers

Self-Sticking Miniature-Size Serial Number Markers for electronic components, in sizes .060" x .200" and .120" x .200", are available from W. H. Brady Co. Serial Numbers are accurately and legibly printed on the markers. Special materials developed especially for the markers stick-at-a-touch to the component body. They stay stuck at temperatures up to 300°C (572°F.). Markers are also printed with special information, such as component value, JEDEC Type, polarity symbol, manufacturers trademark, date code, or any combination of these. Many different materials are available in thicknesses from .001" to .004".

Circle 114 on Reader Service Card

Bell Jar Vacuum Coaters

Two new bell jar vacuum coating systems offer advanced performance both in production of thin metallic films for microminiature electronics and in research on molecular electronic vacuum coatings, according to the manufacturer, NRC Equipment Corporation. Model 3164 has the new high speed NRC 4" fractionating vacuum oil diffusion pump with speed rating of 750 liters per second. Model 3166 uses NRC's counterpart 6" pump, rated at 1550 liters per second.

Circle 112 on Reader Service Card

Alloy Spheres

Tin-selenium, tin-tellurium, gold-tin and gold-tellurium spheres used in the

manufacture of gallium-arsenide semiconductor devices are available from Alpha Metals, Inc. These spheres are produced in diameters as small as .002". They are available with up to .6% selenium and 1.7% tellurium.

Circle 104 on Reader Service Card

Recording Curve Tracer

Aerotronic Recording Curve Tracer, Model 558, is designed to plot both the forward and reverse characteristics of all diodes, including Zeners, either automatically or manually with better than ± 1% accuracy. The forward voltage is fixed at 1.0 volt full scale with five forward current ranges of from .5 milliamps to 50.0 milliamperes per inch. There are seven reverse voltage ranges from 1.0 to 100.0 volts per inch and three reverse current ranges of 1.0, 10.0 and 100 microamperes per inch.

Circle 136 on Reader Service Card

Fast Switching Diode

A new hermetically sealed miniature glass diode with very low capacitance and especially applicable for fast switching applications has been developed by United Components, Inc. Type UCI-362 has a shunt capacitance of 1 uuf and is designed for switching in the nanosecond range. It fully meets all military requirements for mechanical and environmental conditions.

Circle 124 on Reader Service Card

Electrolytic Capacitors

Single-ended plastic-encased miniature electrolytics for use on printed wiring boards used for transistor-type electronic circuits are now available from the Sprague Electric Co. in a series of 142 standard ratings ranging from 3 to 50 volts, as well as in special multiple ratings tailored to exact circuit needs which

contain both dual and triple-section capacitors. The latter are expected to effect significant economies in the design of small radio receivers and similar equipment according to the company. Complete performance details are given in Engineering Bulletin No. 3060A.

Circle 103 on Reader Service Card

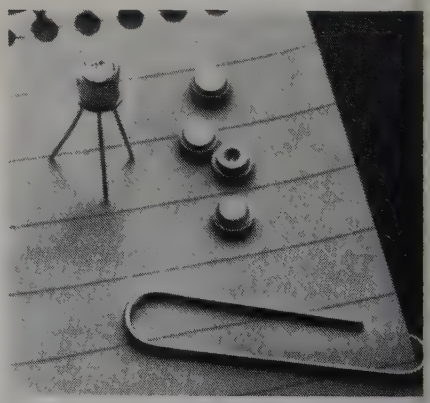
Float Zone Single Crystal Silicon

Allegheny Electronic Chemicals Company is offering an improved kind of float zone single crystal silicon. "Controlled" Float Zone is available in crystal diameters ranging from as small as ⅛" up to ¾", and is free from lineage and gross defects which are commonly found in ordinary float zone crystal, according to the company. Dislocations may be had in low ranges of 5,000/cm². Resistivity tolerances are held extremely close. Both (111) and (100) orientations are available.

Circle 109 on Reader Service Card

Germanium Tunnel Diodes

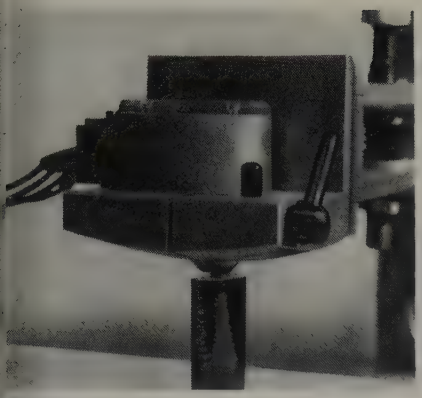
General Electric Company has announced four new microwave frequency germanium tunnel diodes housed in a new miniature package. Two operate at



frequencies up to 3500 mc and the other two at frequencies up to 4600 mc. Typical inductance is 0.4 mμh. This parameter is held to a maximum of 0.5 mμh. The devices have typical total capacities of 7, 4, 14, and 7 picofarads, respectively. Typical peak point current ratings of the 1N3218 and 1N3218A are 1.0 ma and of the 1N3219 and 1N3219A are 2.2 ma. This parameter rating is controlled to within plus or minus 10%. The new devices are also designed for application in radar, very high frequency amplifiers and oscillators and other "S" band equipment. They are available in production quantities.

Circle 101 on Reader Service Card

Semiconductor Compound



Gallium Arsenide in single and polycrystal forms for use in tunnel diodes, varactor diodes, microwave diodes and transistors is now available from Alloys Unlimited Chemicals, Inc., in resistivity ranges of .0X to .000X Ohm-Cm for p-type devices and .X to .000X Ohm-Cm for n-type devices. It has a carrier concentration of 4 x 10^{16} carriers/cm^3 to 5 x 10^{19} carriers/cm^3 and mobility up to and better than 4500 cm^2 volt-sec. The compound can be supplied undoped or doped with either zinc, cadmium, manganese, tellurium or tin.

Circle 110 on Reader Service Card

Liquid Resin

Isochem Resins has released a new liquid Novalac Resin for ultra high temperature potting, casting, dipping and coating compounds, Isochemrez 460 series. This Resin is stable from −60° through +280°C and when used with Hardener #63, will not degrade under long high temperature operation. Available in various colors or filled and unfilled and can be modified to customer's specifications.

Circle 126 on Reader Service Card

Power Supply for Plug-In Units

New electronically-regulated power supply, Type 132, provides an easily-portable housing for any Tektronix A-

to Z Plug-In Unit, thus enabling the many plug-ins to be used with or without on oscilloscope in a wide variety of applications. Internal amplifier has a frequency response of d-c to 22 mc, risetime of 15 nsec, noise level less than 0.5 mv, peak-to-peak (referred to internal amplifier input). Front-panel terminals permit push-pull or single-ended + or − input.

Circle 102 on Reader Service Card

Crucible Pot Furnace

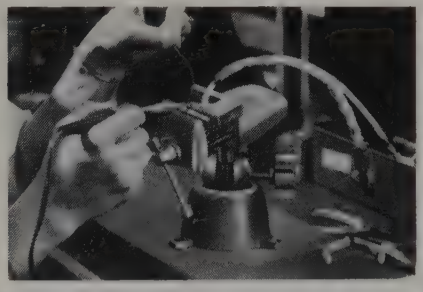
A new electric crucible pot furnace with atmosphere retort and forced air cooling pit has been added to its line of equipment for production of semiconductors, solid state and other electronic devices according to an announcement by Lindberg Engineering Company. Type RDPC-77 is rated at 2250°F (1232°C) maximum chamber temperature. Chamber is

7″ diameter by 7″ deep. Atmosphere retort with a clear working area of 4-½″ diameter by 6-½″ deep can be used to 2150°F.

Circle 105 on Reader Service Card

Work Positioners

Hunter Tools announces the availability of a complete line of work positioners for holding all sizes and shapes of small parts. By simply tightening the one con-



trol knob on the side of the positioner, the head of the positioner can be turned to any desired angle and set firmly. Nylon jaws are available to protect delicate parts. Size of the work positioner illustrated is 6½″ high and 5½″ wide. Jaws will open to receive up to a 2¼″ part.

Circle 106 on Reader Service Card

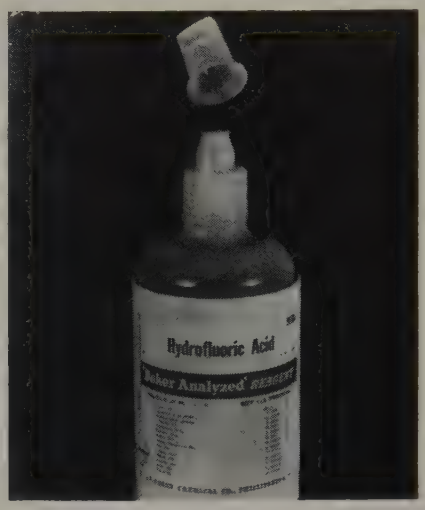
Silicon Diodes

Three mil-qualified silicon diodes are available from Rheem Semiconductor Corporation. USN 1N483B, USN 1N485B and USN 1N486B have ultra-low leakage (typically 1μA @ 150°C) and high forward conductance (100mA minimum @ 1V). The reverse voltages range up to 250 volts. They are in standard glass, hermetically sealed DO-7 JEDEC outline packages. In addition to the mil-spec, these types may also be ordered per Mark X, master test specification for high reliability silicon diodes.

Circle 125 on Reader Service Card

Bottle For Hydrofluoric Acid

The J. T. Baker Chemical Co. announces a packaging advance with the introduc-



tion of the new Adjusta-Flow 1 lb. container for 'Baker Analyzed' Reagent Hydrofluoric Acid. The user can actually dial the rate of flow from a single drop to a steady controlled stream, utilizing calibration marks on the bottle and closure to obtain a precise rate of flow. This eliminates removing the cap or puncturing a diaphragm and contributes to greater laboratory safety.

Circle 108 on Reader Service Card

Silicon Mesa Transistors

2N1131 and 2N1132 high-speed medium-power p-n-p transistors were announced by Texas Instruments Incorporated. The two double-diffused silicon mesa transistors are specially designed and engineered to operate in both linear and non-linear complementary symmetrical circuitry with TI 2N696 and 2N697 n-p-n silicon transistors. Both are available in a welded TO-5 package providing two-watt dissipation at 25°C case temperature, BV_{CBO} = 50 volts, BV_{CEO} = 35 volts and BV_{EBO} = 5 volts. I_{CBO} is one microampere are 30 volts at 25°C ambient temperature and 100 microamperes at 150°C ambient temperature.

Circle 133 on Reader Service Card

Gain Test Set

Dynatran Model 1828, 20 mc Gain Test Set provides direct readings of the 20 mc grounded emitter current gain (h_{fe}) on a large easy to read panel meter. The gain

ranges are 0-3, 0-10 and 0-30. The instrument includes a built-in socket which accommodates both long and short lead transistors. Available with and without built-in regulated bias supplies for both n-p-n and p-n-p transistors. This instrument is particularly useful for testing mesa, drift and surface barrier transistors.

Circle 115 on Reader Service Card

(Continued on page 66)

Market News . . .

Sales

According to the Electronics Division, BDSA, of the U.S. Department of Commerce, the total shipments of semiconductor devices increased sharply during the fourth quarter of 1960, despite the continuing decline in average unit prices. Unit output of transistors increased over 30% although average unit prices declined over 11%. The following tables indicate estimated shipments and estimated unfilled orders as of the end of 1960.

Table 1.—Estimated Shipments of Semiconductors during the Fourth Quarter of 1960.[1]

Category	Quantity (in thousands of units)			Value (in millions of dollars)		
	Total	Military	Non-military	Total	Military	Non-Mil
SEMICONDUCTOR DEVICES	98,078	25,457	72,621	144,101	65,576	78,525
Diodes, rectifiers and related devices	58,544	18,631	39,913	61,196	28,668	32,528
Germanium diodes and rectifiers	27,567	7,670	19,897	11,757	4,673	7,084
0-30 ma	15,360	3,407	11,953	6,182	2,321	3,861
31-100 ma	9,313	3,024	6,289	4,000	1,816	2,184
Over 100 ma	2,894	1,239	1,655	1,575	536	1,039
Silicon diodes and rectifiers	23,749	9,542	14,207	34,042	17,206	16,836
0-30 ma	5,545	3,240	2,305	8,565	5,686	2,879
31-100 ma	4,649	2,573	2,076	6,357	4,053	2,304
101-550 ma	6,635	1,817	4,818	7,771	3,329	4,442
551 ma-3 amps	5,115	1,627	3,488	5,567	2,229	3,338
Over 3 amps—35 amps	1,680	248	1,432	3,867	1,162	2,705
Over 35 amps	125	37	88	1,915	747	1,168
Zener diodes	2,007	928	1,079	8,102	3,752	4,350
Microwave diodes	314	314	[3]	1,454	1,454	[3]
Infra-red and other semiconductor photo cells, except solar cells	145	12	133	864	430	434
Other[4]	4,762	165	4,597	4,977	1,153	3,824
Transistors	39,534	6,826	32,708	82,905	36,908	45,997
Germanium	36,618	4,597	32,021	54,871	15,689	39,182
0-125 mw	11,355	1,910	9,445	14,451	5,047	9,404
126-999 mw	21,232	2,207	19,025	31,010	7,950	23,060
1 watt and over	4,031	480	3,551	9,410	2,692	6,718
Silicon	2,916	2,229	687	28,034	21,219	6,815

Factory sales of transistors in February gained by more than 1 million units and $2.7 million over totals for January, according to statistics released by the Marketing Data Department of the Electronic Industries Association.

	Factory Sales (Units)	Factory Sales (Dollars)
February	13,270,428	$25,699,625
January	12,183,931	22,955,167
Jan.-Feb. 1961	25,454,359	48,654,792
Jan.-Feb. 1960	19,134,292	49,546,150

Standard Rectifier Corporation, Santa Ana, Calif., has announced the appointment of two additional sales representatives. They are: Alex Corbett, Jr., St. Petersburg, Fla., who will service that state and surrounding territory; and Engineering Services Co., St. Louis, Mo., who will cover Cedar Rapids, Iowa, Kansas City, Mo., Wichita, Kans., and Southern Illinois.

Electronic Metals and Alloys Inc., Watertown, Mass., has announced the appointment of the Dage Corp., New York, N.Y., as technical sales representatives for their complete line of metals, alloys and analytical services for the electronic industry. Dage Corp. will provide complete sales service in Europe, Japan, and Australia.

Table 2—Semiconductors: Manufacturers' Unfilled Orders as of December 31, 1960[2]

Category	Quantity (in thousands of units)			Value (in millions of dollars)		
	Total	Military	Non-military	Total	Military	Non-M
SEMICONDUCTOR DEVICES	116,267	32,739	83,528	152,933	62,460	90,47
Diodes, rectifiers and related devices	67,932	23,829	44,103	57,121	24,461	32,66
Germanium diodes and rectifiers	44,186	15,679	28,507	15,153	6,904	8,24
0-30 ma	29,862	6,547	23,315	8,982	2,529	6,45
31-100 ma	11,995	7,915	4,080	5,074	3,901	1,17
Over 100 ma	2,329	1,217	1,112	1,097	474	62
Silicon diodes and rectifiers	19,917	7,179	12,738	29,998	12,531	17,46
0-30 ma	3,776	1,938	1,838	3,977	2,490	1,48
31-100 ma	3,707	2,481	1,226	6,328	4,216	2,11
101-550 ma	7,197	1,582	5,615	9,612	2,845	6,76
551 ma—3 amps	2,477	941	1,536	3,200	1,426	1,77
Over 3 amps—35 amps	2,646	201	2,445	5,371	891	4,48
Over 35 amps	114	36	78	1,510	663	84
Zener diodes	1,628	736	892	7,000	3,043	3,95
Microwave diodes	125	125	[3]	761	761	
Infra-red and other semiconductor photo cells, except solar cells	122	16	106	909	422	48
Other[4]	1,954	94	1,860	3,300	800	2,50
Transistors	48,335	8,910	39,425	95,812	37,999	57,81
Germanium	46,240	7,284	38,956	71,921	19,696	52,22
0-125 mw	8,082	3,953	4,129	16,827	9,731	7,09
126-999 mw	34,411	2,528	31,883	45,124	7,135	37,98
1 watt and over	3,747	803	2,944	9,970	2,830	7,14
Silicon	2,095	1,626	469	23,891	18,303	5,58

[1]Estimated total industry shipments including intra-plant and inter-plant transfers.
[2]Estimated total industry unfilled orders.
[3]Nonmilitary orders for microwave diodes are combined with military orders to avoid disclosure of proprietary information.
[4]Includes diodes and rectifiers made from materials other than silicon and germanium, tunnel diodes, controlled rectifiers, solar cells, and other special semiconductor devices which must be combined to avoid disclosure of proprietary information.
Source: The quarterly Joint Survey of Production Capabilities for Electronic Parts conducted by the Electronics Production Resources Agency of the Department of Defense, and the Electronics Division BDSA.

Diotran Pacific, of Palo Alto, California, manufacturers of semiconductor production equipment, has announced the appointment of five representative organizations for field sales. They are: Heim and Scheer, Hollywood, California, who will handle Southern California and Arizona; McKnight Company, Menlo Park, California, to serve the Northern California region; Walter LaChicotte, New York, to handle all export sales to Europe and Japan; Fred Sylvester, Springfield, New Jersey, to serve New York, New Jersey and Pennsylvania, and T. Kennedy, Wakefield, Mass., to represent the New England area.

The Japanese Government's Foreign Capital Council has formally approved the agreement between Yaow Electric Co., Ltd. and Western Electric Co., which will permit the Japanese firm to receive technical licenses from Western Electric for the manufacture of transistors and diodes.

The Japanese Government has removed foreign currency restrictions on imports of about 20 industrial and consumer electronic items. Among these are germanium transistors, 30 cycles or less and 10 watts or less.

A tangible market has been opened to semiconductor manufacturers by the introduction of silicon rectifiers in the propulsion equipment of the Pennsylvania R.R. and the New Haven R.R. The new equipment for the Pennsylvania was furnished by Westinghouse Electric Corp., while the General Electric Co. furnished the equipment for the New Haven.

rices

Sylvania has added two new silicon epitaxial mesa transistors o their epitaxial line. Types 2N1958 and 2N1959 have a total witching time of 105 nanoseconds, are priced at $19.50 and $21 ach respectively in quantities from 1-99. In lots between 100 nd 999 they are priced at $13 and $14. The firm has also an- ounced prices on a miniature tunnel diode which oscillates at requencies of 10 kmc and above. The unit D-4168-D is priced t $400 in lots of 1 to 9. An 8 kmc unit is also being sampled t $300 in the same quantities.

The Lansdale Division of Philco is offering production quanti- ies of germanium backward diodes for the first time. Packaged n the T0-18 case the T1977 devices are available at $4.00 each. he development of the backward diode is most significant to unnel diode circuitry in that the new device can operate at low orward voltage levels while providing unidirectional flow of nformation within a system.

Texas Instruments, Inc., has authorized its distributors to ell any quantity of nine types of silicon industrial-type tran- istors. These are T1480 through T1484 and T1492 through T1495. n lots between 100 and 999 prices are: 480, $2.05; 481, $2.30; 82, $2.95; 483, $3.25; 484, $3.70; 492, $1.80; 493, $1.95; 494, $2.10 nd 495, $2.30.

Hoffman Electronic Corp.'s Semiconductor division has lowered prices 10 to 40% on its silicon diode and its backward (Uni- Tunnel) diode lines. Prices of the 1N2929-33 have been reduced o $11.10 each. Backward diodes Hu-5, Hu-10, Hu-25, Hu-50, Hu-75, Hu-100 are now $7.50 each. The A types Hu-5A through Hu-100A are now $9 each. The firm has also announced produc- ion of a new series of glass, temperature-compensated, silicon, Zener-reference diodes. These subminiature 500-milliwatt units are designated 1N935 through 1N939. Prices have not yet been established.

Hughes Semiconductor division is marketing four new n-p-n silicon mesa switching transistors and four new p-n-p silicon mesa transistors. These are priced as follows:

n-p-n	1-99	100-999	p-n-p	1-99	100-999
2N706	$12.65	$ 9.50	2N1631	$19.35	$14.50
2N707	21.25	16.00	2N1131A	25.60	19.20
2N708	N.A.	N.A.	2N1132	21.00	15.75
2N753	16.45	12.35	2N1132A	49.25	37.00

General Electric Co. has available four new microwave frequency germanium tunnel diodes housed in a new miniature package. Types 1N3218, 1N3218A, 1N3219 and 1N3219A are available in production quantities from $20-$30 each.

Canadian General Electric Co., Ltd., Toronto, is offering eight silicon mesa transistors designed for medium power audio to medium frequency applications. Types 2N497, 2N497A, 2N498, 2N498A, 2N656, 2N656A, 2N657, 2N657A are priced from $21.32 to $21.58 each to OEMS.

Micro State Electronics Inc., Murray Hill N.J., has announced prices on its line of germanium tunnel diodes in quantities up to 24 units. They are priced each as follows: MS222, $30; MS223, $45; MS224, $95 and MS242, $25. They also are marketing varactor diodes, diffused junction mesa units. These are priced each in similar quantities as follows: MS262, $125; MS263, $175; MS264, $225; MS265, $320; and MS266, $425.

R.C.A., Somerville, N.J. has introduced a commercial diffused 12 ampere stud-mounted, diffused junction, silicon rectifiers. In quantities of 1000 units these are priced each as follows: 1N1199A, $2.40; 1N1200A, $2.85; 1N1202A, $4.05; 1N1203A, $5.25; 1N1204A, $6.35; 1N1205A, $8.90, and 1N1206A, $10.60.

Suppliers

Norton Co., Worcester, Mass., is offering a new machine for slicing and lapping semiconductor materials.

Allegheny Electronic Chemicals Co., Bradford, Pa., is producing single crystal silicon by a new "controlled" float zone method. This material is available in diameters from ⅛ to ¾ inch as well as in dice form. In resistivities of less than 50 ohm-cm., it is priced at $1.73 a gram.

Merck and Co., Inc., Rahway, N.J., has named Shin-Etsu Chemical Industry Co., Ltd., sales agent in Japan for their silicon single crystals Approximately 700 kilograms of these crystals were imported last year from the United States. Shin-Etsu is planning to expand its silicon purifying facilities to produce about three tons of single crystals per year.

Semi-Elements, Inc., Saxonburg, Pa., has begun producing gadolinium selenide, which is a promising thermoelectric material with a potentially high Z factor. Undoped material as well as n-type and p-type material, is available in research quantities of 100 grams, priced at $5.50 a gram.

Kulicke and Soffa Manufacturing Co., Philadelphia, Pa., exclusive marketing representative for Electroforming Consultants, Inc., has announced the availability of masks for laying down geometries for high frequency semiconductors within three working days—on special order but at no extra cost.

Fanon Transistor Corp., Newark, N.J., plans to issue the following silicon mesa power transistors: 2N1724, 2N1616, 2N1617, 2N1618, 2N389, 2N424, 2N389A, 2N424A, 2N1722, 2N1210, 2N1211, 2N1620 and the 2N1487 family. Price schedules have not been announced as yet.

Distributors

Yonkers Electric Supply Inc., Yonkers, N.Y., has been named industrial distributor for Sarkes Tarzian Inc.'s line of silicon rectifiers, Zener diodes and voltage regulators.

Fairchild Semiconductor Corp., has appointed the G.S. Marshall Co., San Marino, Cal. as their distributor for the greater Los Angeles area. This brings the total number of Fairchild distributors to seventeen.

Dickson Electronics Corporation, Scottsdale, Arizona, has appointed three new industrial distributors. They are: D and H Distributing Company, Inc., Baltimore 30, Maryland; Pace Electronic Supplies, Inc., Chicago 48, Illinois; and Wesco Electronics, Pasadena, California. Also named are the following manufacturers representatives: M. L. Spitzer Company, Rochester, New York—serving upper New York state; and Robert R. Thomas Company, Dallas, Texas. The latter will cover Texas, Oklahoma, Arkansas and Louisiana.

The Birtcher Corporation's Industrial Division has announced the appointment of R. P. Luce and Company of Summit, New Jersey, and Adelta Co., of Dallas, Texas as distributors for its line of tube, transistor and component retention and cooling devices. Luce will act as distributor in the State of New Jersey and Southern New York state. Adelta will act as distributor throughout the state of Texas.

Financial

General Electric Co. has reported sales of $992,622,000 for the first quarter ending March 31, 1961, a gain of 3.7% over the $957,433,000 for the same period in 1960. Net income was $42,476,000 equal to 48¢ a common share against $52,514,000 or 60¢ a share for the first quarter in 1960.

Alloys Unlimited, Inc., producers of materials and sub-assemblies for semiconductor manufacturers, in a first financial report, announced that its net sales for the six month period ending February 28, 1961 amount to $1,329,225.59. Profits after taxes were $81,868.49, or fourteen cents a share on 593,003 shares. In the year ending August 31, 1960, Alloys Unlimited and its subsidiary, Alloys Unlimited Chemicals, Inc., had net sales of $1,467,639; net earnings were $143,766.

Texas Instruments has reported sales of $58,977,000 for the first quarter of 1961 which is a 5% increase over the $56,198,000 for the same period in 1960. Earnings, however, were $3,773,000 down 4% from $3,930,000 last year.

Alloys Unlimited, Inc., now operates Electronics Glass & Ceramic Corp., Cambridge, Mass., and has also recently acquired Veritron West, a glass-to-metal seal manufacturer in North Hollywood, Cal. Both firms are wholly owned subsidiaries. The firm has also reported net sales in 1960 of $1,467,639 or 33¢ a share.

Trans-Sil Corp., Englewood, N.J. has become a wholly-owned subsidiary of Raytheon Co. The firm will continue to market its existing line of modular silicon rectifiers.

Nuclear Corp. of America, New York has purchased U.S. Semiconductor Products, Inc., Phoenix, Ariz. for about $4 million.

C. P. Clare Transistor Corp., Glen Head, L.I., N.Y., a subsidiary of Universal Controls, Inc. may transfer its operations to Europe or Israel. The firm, which manufactured germanium transistors closed its doors in March.

(Continued on next page)

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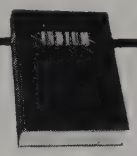

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Hoffman Electronics Corporation has reported that its fir three months' sales in 1961 were $16,098,315, the highest in a quarter year in the Company's history, and resulted in a pro after taxes of $256,668, representing $.16 a share. The reco sales volume for the first quarter compares with $10,215,897 the same period in 1960 and the profit after taxes of $256,6 compares with $2,530 for the first 1960 quarter.

Merck & Co., Inc. had consolidated net sales for the first thr months of 1961 or $54,977,000, compared with $55,759,000 for t first three months of 1960. Net income after taxes was $6,160,0 for the 1961 quarter, equal to 57 cents per share of comm stock outstanding, a decline of 17 per cent from the $7,425,0 or 69 cents per share earned in the first quarter of 1960.

Rheem Semiconductor Corporation, Mountain View, Calif., ported its highest sales month in March of this year. T continues a trend of markedly increased sales each quar since operations started in the third quarter of 1959. The pare company has announced that their over-all results improv in March, but they sustained a loss for the first quarter 1961. Net loss for the quarter ended March 31 was $244,749, a loss of 13 cents a common share after providing for preferr dividends.

Loral Electronics Corporation, New York, has announced th agreements have been executed under which it will acqui Accurate Specialties Company, Inc., Hackensack, N.J. The tran action will be consummated on the basis of an exchange stock at the ratio of one share of Loral for each two and on half shares of Accurate. A total of approximately 150,000 shar of Loral will be involved in the transaction.

Youngwood Electronic Metals, Inc., Youngwood, Pa., has file a registration statement with the Securities and Exchange Com mission seeking registration of 75,000 shares of common stoc to be offered for public sale at $4 a share. The firm is engage in the design, development and manufacture of precision par or stampings, principally used in the semi-conductor industr

The board of directors of Temperature Engineering Corpora tion, Riverton, N.J., has approved an agreement to purcha the Jacksonville Metal & Plastics Co., Jacksonville, Fla.

Expansion

Fairchild Semiconductor Corp., has started construction o a 40,000 square foot addition to their main plant in Mounta View, Calif. A half-million dollars will be expended on th new addition; which will increase the main plant's area 108,000 square feet.

Merck & Co., Inc., has recently authorized a major capit expenditure for construction of a full-scale plant for produc tion of epitaxial silicon wafers. In addition, a pilot plant f experimental production of epitaxial germanium wafers is i operation. The silicon unit is being constructed at Danvill Pa., site of Merck's single crystal silicon plant. This is th

Diotran Pacific, of Palo Alto, California, manufacturer semiconductor production equipment, announces the purcha of a building site in Palo Alto where their new quarter-millio dollar plant, laboratory and office facilities will be constructe The proposed two story structure, with 20,000 square feet planned working space, is scheduled for completion late in th year.

Mitronics, Inc., Hillside, N.J., will move into its new build ing of approximately 30,000 square feet, in July. The new build ing is located on Floral Avenue in Murray Hill, New Jerse Mitronics, Inc., specializes in the manufacture of metallize ceramic sub-components, ceramic to metal seals and assemblie

New Firms

Mitsubishi Electric Manufacturing Co., Ltd., Tokyo will es tablish a joint firm with Thompson Ramo Wooldridge, Inc Los Angeles to manufacture silicon semiconductor component and automatic factory control equipment with technical ai from Pacific Semiconductor Inc., a subsidiary of TRW. Th new firm will be named Mitsubishi-TRW Co., Ltd.

Micronics, Inc., has been established in Minneapolis to engag in research and development of such solid state devices as tran sistors as well as vacuum devices. Present capital is $270,000

Electron division of Controls Co. of America plans to marke its first transistor line later this year. The firm has now i development or in pilot production, a logarithmic forward con ductance diode, diffused-type Zener diodes, a four-layer, o switching diode.

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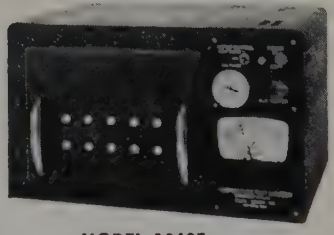

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Ph.D. with basic study of circuit functions and how they can be achieved using solid-state techniques.

COMPUTER SCIENTIST, MICROELECTRONICS— $16,000
Ph.D. to work on application of magnetic elements to digital computer circuits, applying elements to logic circuits, and random access storage. Current research emphasis is in the fields of plated magnetic materials and magnetic thin films. Scientific background required rather than the application.

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Ph.D. with basic research in ferrites, oxide semiconductors thermoelectrics, or piezoelectrics.

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Semiconductor Manufacturing firm has recently reorganized their entire staff and are making a concentrated effort to enhance their position as one of the leaders in the semiconductor industry. They have recently built a new facility in a beautiful and desirable area on the seashore, with year-around swimming and outdoor recreation facilities available. The following list is representative of the openings now existing, but does not include all positions available. Since this is an accelerated expansion move, opportunities for advancement are excellent.

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Ph.D., Physics, E.E., or Physical Chemistry, with previous background in management R&D facility. Should be capable of attracting additional well qualified research scientists. Salary open, but will be in the $18,000-$30,000 range.

SR. DEVELOPMENT ENGINEER
Ph.D., Physics, or E.E. (M.S. with strong development beckground will be considered). To work in development of silicon mesa or planar devices. $14-$18,000.

SR. SCIENTIST, Applied Research
Ph.D., with three or more years experience in R&D, for a semiconductor research group on diffused devices. Must be capable of leading group of scientists and directing their efforts. $16-$20,000.

SR. DEVELOPMENT ENGINEER
Ph.D., Physical Chemistry, Physics or E.E., to work on development processes, silicon epitaxial devices. $14,000-$18,000.

MATERIALS MANAGER
Ph.D. or M.S. in Metallurgy, Physical Chemistry, or Physics, to head up materials section. Should have several years experience in crystal growing, and supervisory experience. $15,000.

PRODUCTION ENGINEERS
Require several men with four or more years experience in production engineering and in processes, diffusion, etching, photo-chemistry. M.S. degree, and capable of assisting management functions and training young, inexperienced engineers. To $10,000.

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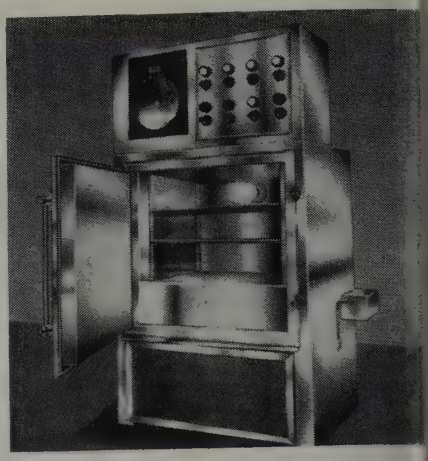
New Products

(from page 61)

Temperature-Humidity Chamber



Hudson Bay Co., environmental division of Labline, Inc., announces the addition of a 4-cubic foot upright chamber to its present line of temperature-humidity test cabinets. This high-performance unit has a temperature range of 0° to 200° F with a control tolerance of ±2° F and a humidity range of 20% to 95% RH within ±5%. The "Environ-Cab" has wide usage for environmental testing of chemicals, electronic components, paints, plastics, packaging, protective coatings, etc., and for JAN & MIL specifications.

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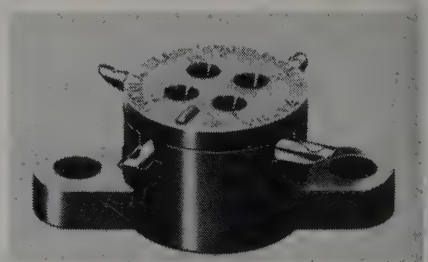
Transistor Test Set

Owen 210-A Transistor Test Set is an a-c operated, portable device for measuring the h-parameters and leakage currents of small transistors and diodes. D-C currents to 7 ma and potentials to 70 volts are available. An internal oscillator and a-c millivolt meter provide dynamic tests at a frequency of 1500 cycles. With the addition of a variable-frequency laboratory oscillator and a-c voltmeter, alpha cutoff, beta cutoff, collector capacitance, and other high frequency measurements can be made.

Circle 138 on Reader Service Card

Transistor Breadboard Socket



Pomona Electronics Co., Inc., has introduced a new Surface Mounted Transistor Breadboard Socket designed for use with JEDEC 30 type transistors. Model XS-T4 features: closed entry socket contacts, silver plated beryllium copper contacts, accessible contact tabs, contacts clearly identified, low loss micafilled phenolic casting, per MIL-M-14, type MFE.

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Improved Laboratory Bottle

The Nalge Co., Inc. announces a new flexible polyethylene wash bottle spe-

cially designed and fabricated for laboratory work of all kinds. The bottles have a new molded leakproof connection for the tubing located in the shoulder instead of the cap. At the same time, the bore of the tubing has been enlarged so that more liquid can be delivered, if desired; and the bodies have been made of a more flexible resin to make manipulation in the laboratory easier.

Circle 116 on Reader Service Card

Hardboard Dicing Blocks

Great savings on materials, maintenance and tool costs on just one operation, through the use of hardboard for dicing blocks, have been claimed by a manufacturer of transistors. Where they formerly were using 2" squares of ⅜" thick ceramic for dicing blocks, the company now is using ¼" Masonite Tempered Duolux sanded to .230 plus or minus .005 and a plus or minus 1/64" tolerance in cutting and squareness. These finished blocks also are 2" square and are supplied by Masonite Fabricators.

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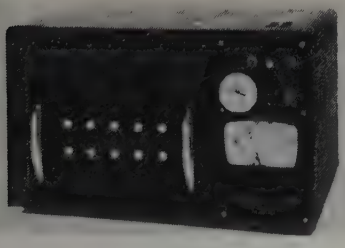
Rapid Temperature Cycling



The development of a new temperature chamber, Model 1060F, has been announced by Delta Design, Inc. This portable table top model is designed for the user who wants the ultimate in control accuracy and minimum thermal gradient across his test specimen without waiting. The unit is capable of completing a cycle between −100°F and +500°F in less than 12 minutes. Control accuracy is ±½°F. Test volume is 10" x 7" x 7". It can be cycled at shocking rates between preset temperatures by use of the Delta MR-1 Timer. At −65°F consumption of liquid CO^2 is less than 3½ lbs per hour. The unit weighs only 40 pounds which allows it to be carried to the point of test.

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(*Continued on next page*)

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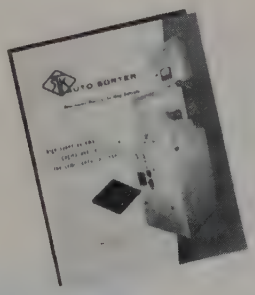

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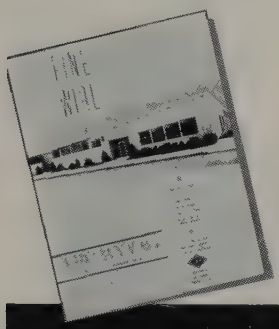

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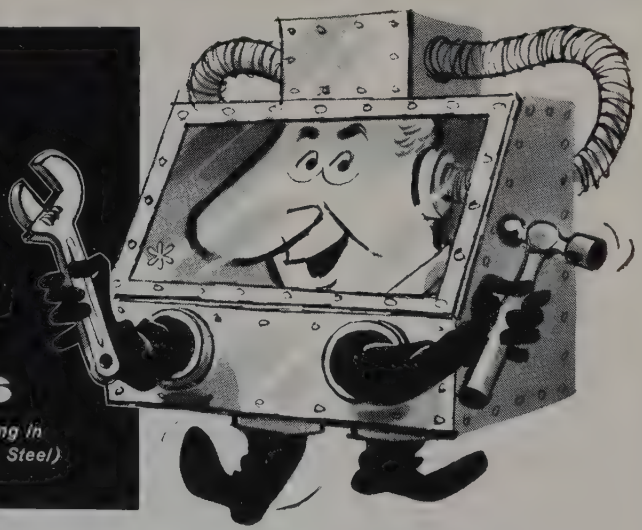

* Here's the real "inside dope" and we're not referring to the happy young fellow portrayed above. (He's not even a member of our organization)

We are a division of Kewaunee Manufacturing Co., specializing in engineering and production of highly technical equipment and apparatus for research and industry. Our experience and facilities qualify us to custom design and manufacture, or assemble from stock, any of the following types of enclosures: glove, vacuum and dry boxes; dust free enclosures; and controlled atmosphere systems.

That's why we readily say, "We make all kinds of boxes."

For complete information, call or write

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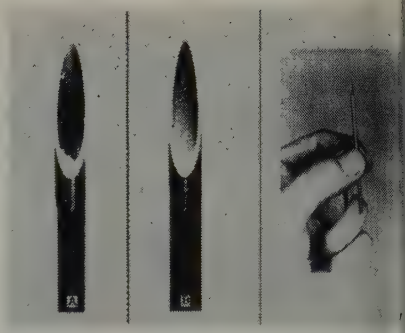
Circle No. 36 on Reader Service Card

Airbrasive Tool



Deburring with abrasive particles p pelled by gas at high speeds is possi with equipment known as the Industri Airbrasive Unit, manufactured by S White Industrial Division. Airbrasive an industrial tool for cutting or abra ing hard, brittle materials: for exam cutting silicon and germanium; cutti shapes out of a tungsten sheet 0.00 thick, etc.

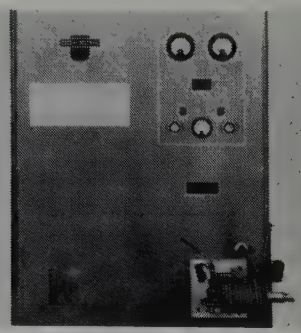
Circle 142 on Reader Service Card

Flow Actuated Electrical Switch

The completely adjustable Peeco A tuated Flow Switch offers a simple low cost means of providing remote indica tion of pre-set rates of flow of liquid and gases. Starts and stops pumps, valve alarms and signals; efficiently assur controlled blending, mixing, filling ar emptying. They are particularly valuab in Automatic Pump Flow Control, Wate Cooling, Process Blending and Bui Loading Control. Once the setting is ac justed to flow requirements, (can b actuated as low as .25 g.p.m. in quarter inch line) it will infallibly repeat itse under like conditions. Can be installe on either side of the centrifugal pum there is no pipe too large or too small, a cording to the company.

Circle 131 on Reader Service Card

Induction Generator



A 40 mc induction generator capable o continuous operation at 3 KW output i commercially available from Induction Heating Corporation. Depth of penetra tion at 40 mc is .0005" compared to .0017 at 4 mc and .0055" at 400 kc. One of the applications of gas ionization produced by frequencies in this range is the plasma torch. Intense heat is developed in a rapidly moving column of ionized gas which can be directed in the same manner as a torch. High resistance materials such as semiconductors, readily can be heated.

Circle 107 on Reader Service Card

Core Driver Diode

A new high conductance core driver Laminar* diode was announced by Pacific Semiconductors, Inc. PS9013 has a capacitance of only 7 pf at 9 V reverse; forward current at 0.9V, greater than 500 mA; saturation voltage, greater than 30V at 25°C; I-60 at 25°C, less than .20μA; reverse recovery less than .2μsec. (Switching 500mA forward to −30V reverse recovery to 10K Ohms.) *Laminar is the trademark of multi-layered silicon diodes and transistors manufactured by PSI.

Circle 130 on Reader Service Card

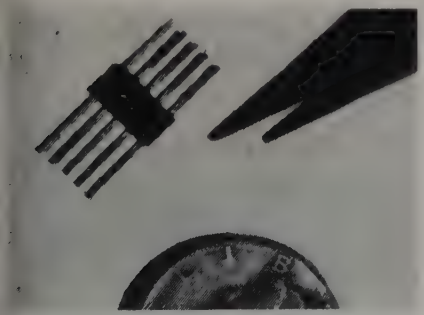
Circuit Breaker

A high-speed milliampere circuit breaker, based on a new physical concept, is now being produced by Orbitec Corporation for protecting transistor circuits against sudden or transient overloads. Model 150 is a small, compact unit that is interposed between a power supply or signal source and the transistor circuitry that is to be protected. The cost of each unit allows a number to be used in parallel arrangements off a common power supply to protect various circuits in an instrument or system. Transistors and other common semiconductor components generally require an overload of at least forty-microsecond duration before they are damaged or destroyed. The Circuit Breaker responds to one-microsecond transients, opening the load within ten microseconds according to the company.

Circle 139 on Reader Service Card

Micrologic Circuits

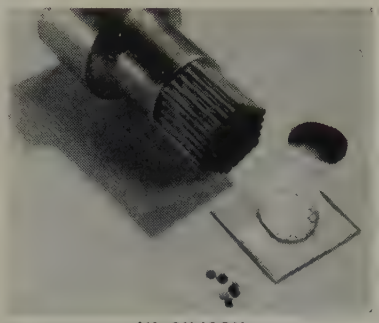
MicroSemiconductor Corporation announces the availability of silicon micrologic circuits. Basic size for 4, 6, or 8



silicon diode configuration is .030 thick x .125 wide x .250 long. Leads are gold plated and ideally suited for welding and soldering techniques. Individual diode electrical parameters are available in excess of 2 nanoseconds recovery and 2 picofarads capacitance. Circuit designers and packaging engineers can microminiaturize with a usable form factor, alleviating much of the interconnection problem. Reliability is increased as the size is reduced.

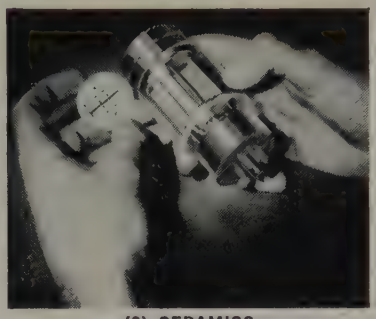
Circle 128 on Reader Service Card

(*Continued on next page*)

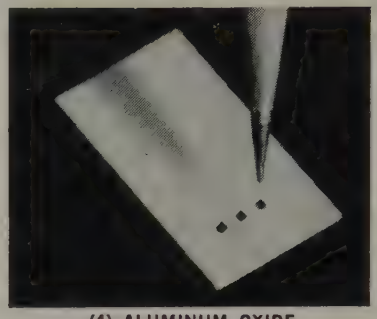


(1) SILICON

(2) FERRITES



(3) CERAMICS



(4) ALUMINUM OXIDE

ULTRASONIC MACHINING: 1. dicing silicon wafers; 2. cutting ferrite cores; 3. cutting holes and slots in ceramic tube spacers; 4. drilling holes in aluminum oxides.

Low-cost, high-speed
PRECISION MACHINING
of hard or brittle materials with
ULTRASONICS

The delicate cutting operations shown above were all performed with Impact Grinders—Raytheon's ultrasonic machines that drill, slice, engrave, trepan or shape hard and brittle materials.

Design, materials and production engineers who have tried this remarkable technique agree that it is the optimum method for machining such materials as silicon, germanium, ferrites, ceramics, carbides and glass.

In impact grinding the tool is made to vibrate ultrasonically as abrasives are introduced between tool and workpiece.

Find out how one of these cost-saving, high-production-rate units can solve your machining problem.

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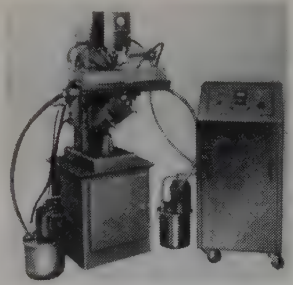

MODEL 2-332 Raytheon Impact Grinder

RAYTHEON

RAYTHEON COMPANY

COMMERCIAL APPARATUS & SYSTEMS DIVISION

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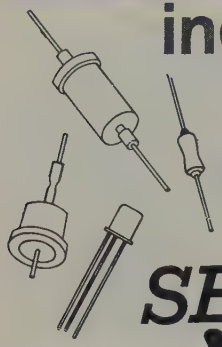

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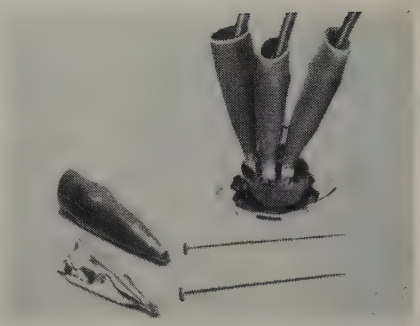
Electric Clip

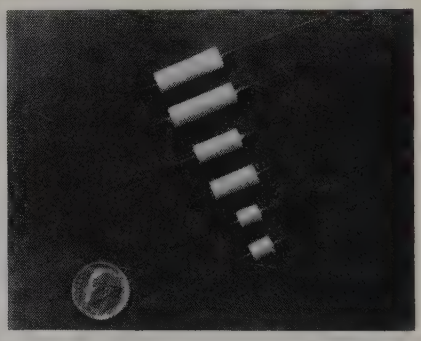


The miniscule tip of Mueller Electric's new "Micro-gator" clip has been tailored to fit the non-stop shrinkage in size of many electrical and electronic components. Insulator and all, the business end of the inch-long Micro-gator is no larger than a pin head, allowing its use on the smallest, tightest-packed terminals, according to the manufacturer.

Circle 140 on Reader Service Card

Ceramic Diode Closure

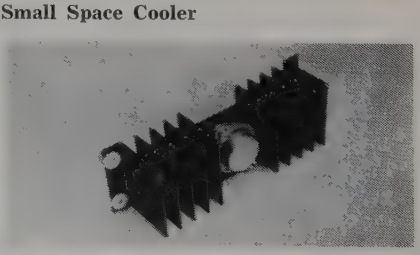
A new ceramic diode closure which meets the hermetic requirements of MIL specifications, and is suitable for thermal cycling between −65° C and +150° C, is now available in both standard and special sizes from Metalizing Industries, Inc., an Accurate Specialties subsidiary. Advantages are: a true hermetic seal, leads can be bent or vibrated with no impair-



ment of the seal, diode will not de-rate after extended storage, requires no final finishing to render it oxidization resistant, inorganic ceramic housing will not affect the semiconductor junction, can be sealed in a matter of seconds using production solder techniques.

Circle 119 on Reader Service Card

Small Space Cooler



Delta-T Semiconductor Cooler Model NC-401 is designed to achieve maximum cooling in minimum space. Models with thermal resistances from 2.8° C/W to .8° C/W for natural convection, and as low as .25° C/W for forced convection, are available from Wakefield Engineering. Optimum spacing of aluminum fins and high base conductivity achieves maximum efficiency per unit weight.

Circle 123 on Reader Service Card

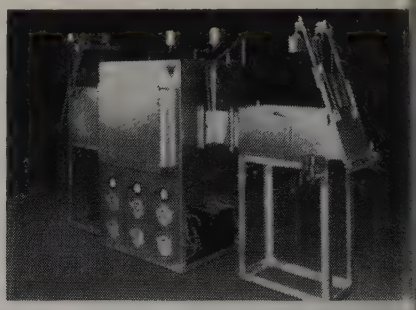
Freezing Point Standards

Freezing Point Standards, furnish[ed] with National Bureau of Standards cer[ti]fied freezing point samples, introduc[ed] by Temptron, Inc., provide an accura[te] and convenient means of reproduci[ng] primary and secondary points in the I[n]ternational Temperature Scale for t[he] calibration of temperature sensing d[e]vices. Features include automatic tem[-]perature control, rapid warm-up, lo[w] freeze-out time (15-20 minutes), and si[m]plicity of operation. The apparatus is d[e]signed to utilize the methods specified [in] Section 3.1 of NBS Bulletin 590, "Meth[ods] of Testing Thermocouples and Therm[o]couple Materials." The Standards a[re] shipped complete and ready for use wi[th] the certified metal samples contained [in] ultra-pure graphite crucibles and he[r]metically sealed to prevent contamin[a]tion.

Circle 127 on Reader Service Card

Heat Treating Furnace

Those performing critical heat treati[ng] processes will find recently announced Pereco Electric Hydrogen Reduction Fu[r]

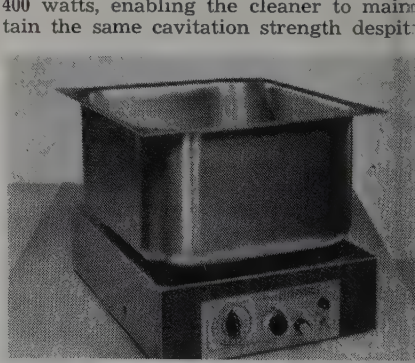


nace of special interest. Model SNX-102[4] 3-zone straight-line unit is designed f[or] hydrogen atmosphere. It consists of a[n] insulated pre-heat zone, a central hig[h] temperature zone, and a water-cooled exit zone. Depending upon the maximum operating temperature requirements, th[e] unit may be equipped with an alloy muf[f]le (1900° F) or with a ceramic muffle (2600° F). Power requirements are 35 kw 440/60/3.

Circle 120 on Reader Service Card

Large Capacity Ultrasonic Cleaner

Will's new model SG-3 Ultrasoni[c] Cleaner is designed for use with tank[s] up to 8 gallons capacity. Although simi[-]lar in design to prototype Model SG-[2] the new unit develops twice the power 400 watts, enabling the cleaner to main[-]tain the same cavitation strength despit[e]



the larger tank volume. Offers compac[t] assembly on a single chassis of both tan[k] and generator; tough magnetostrictiv[e] transducer that will not overheat lo[w] temperature solutions and will operat[e] effectively in fluids up to 400° F.

Circle 121 on Reader Service Card

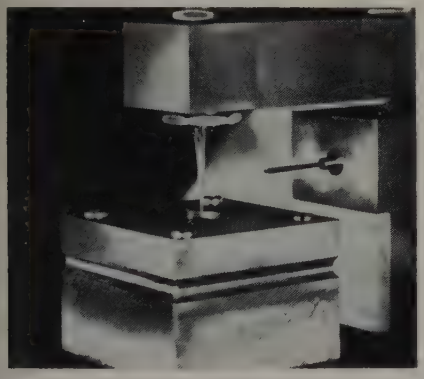
Voltage Monitor

Model 86 Voltage Monitor, a new instrument designed to protect costly equipment, especially large groups of transistors in life runs, has been introduced by Electronic Measurements Company. Continuously monitors d-c power supply output anywhere in the range from 0 to 100 volts, permitting voltage excursions only within a certain bandwidth above and below a nominal selected voltage. Protective operating speed, including relay actuation, is approximately 20 milliseconds. Protective operating speeds on the order of 50 to 100 microseconds can be obtained by using the protect signal to turn off a transistor switch in series with the power supply output. A silicon controlled rectifier shunted across the output can be turned on by the protect signal in 10 to 20 microseconds.

Circle 129 on Reader Service Card

Pyrex Capillaries

A new line of Pyrex glass capillary tubes for thermal compression semiconductor lead bonding machines is an-



nounced by Diotran Pacific. These are precision drawn to accommodate wire diameter sizes ranging from 0.0005" through 0.005". Smaller or larger sizes can be made to order. The tubes are manufactured under closely controlled processes to insure uniformity and to minimize gold wire abrasion under use, thus increasing useful life of capillary.

Circle 122 on Reader Service Card

Power Supplies

PRL Electronics announces a new line of transistor regulated power supplies providing up to 72 Watts of tightly regulated power in a 5" high, 8½" wide and 12¼" portable unit, without the use of blowers. The ST line features a recovery time of less than 25 microseconds, line regulation of ±0.03%, load regulation of 0.05% and ripple of less than 1 MV RMS. Remote programming, remote sensing, series or parallel operation and current limiting protection are all included.

Circle 134 on Reader Service Card

(Continued on next page)

NEW from TI

CRYSTAL RESISTIVITY METER

Measures bulk or slice material

Adaptable for use with other probes

Compact and portable

Texas Instruments new, fully-transistorized Model 635 Crystal ρ Meter is the first portable, a-c instrument designed to measure both bulk and slice resistivity of semiconductor crystals. More accurate and stable readings are achieved by reducing the effect of noise and stray pick-up.

The TI Crystal Resistivity Meter uses a 1000-cycle, square-wave, constant-current source with superimposed d-c bias on probe points to reduce point contact resistance. Ten ranges, selectable by front panel range switch, measure resistivities from .01 to 300 ohm-centimeters, full-scale.

A slice adapter measures resistivity of slices from .007 to .037 inch in thickness. Precision jeweled TI probes are available for measurements of germanium or silicon. The meter can be calibrated for use with other probes having contact spacings from .030 to .080 inch.

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Thermoelectric Modules

Materials Electronic Products Corp. (MELCOR) announced the availability of high-efficiency thermoelectric material and modules for power generation. These units can be used at the temperature range of from −100 to +200°C. Conversion efficiencies up to 6% can be achieved over the temperature range 0 to 200°C. Materials and modules are of a new Bismuth telluride type alloy.

Circle 143 on Reader Service Card

Transistor Transformer Selector Kit

Microtran Company, Inc. announces the availability of a new transistor transformer selector kit composed of 9 subminiature transformers. Also furnished is a Nomograph for determining correct output impedances of Class A and B transistor amplifiers; a conversion chart from DBM to MW; a short form guide to MIL-T-27A; a Cross Reference Index, and terminal connections sheet. The impedance ratings of these transformers cover a range of 150 through 200,000 ohms which will match most of the new transistors.

Circle 118 on Reader Service Card

Terminal Board Assembly

Cambridge Thermionic Corporation announces a new component clip terminal board assembly suitable for quick disconnect of all types of components. Cambion 1422 comes completely supplied and assembled with spring loaded diode clips for easy and positive use by the design engineer. It is extremely useful for semiconductor aging racks and in making prototypes, testing and in test labs. This component board is manufactured from GSG Laminated Silicone Glass Cloth Per Mil-P-997B and measures 2" x 13⅛".

Circle 137 on Reader Service Card

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Circle No. 42 on Reader Service Card

Device Applications

The Delcon Corporation of Palo Alto, California, announces a compact transistorized speech scrambler to insure privacy for all users of two-way radio.

A fully transistorized solid state desk calculator with instant response and no moving parts is announced by Electrosolids Corporation of Los Angeles.

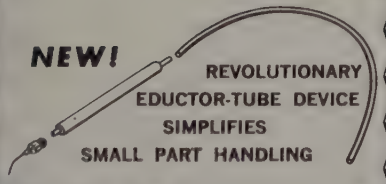
A transistorized, high-gain, low-noise amplifier is available from Quan-Tech Laboratories, Inc., Boonton, New Jersey.

A transistorized version of an image orthicon closed circuit television camera has been developed by Dage Division, Thompson Ramo Wooldridge Inc., Michigan City, Ind.

American Electronics Company, Minneapolis, offers a converter containing a transistor circuit which provides overload and short-circuit protection and assures trouble-free operation.

A portable transistorized alpha-beta-gamma meter was introduced recently by Anton Electronic Laboratories, Brooklyn, N. Y., a division of The Lionel Corporation.

A completely transistorized d-c voltmeter has been developed by Cubic Corporation, San Diego, Calif.



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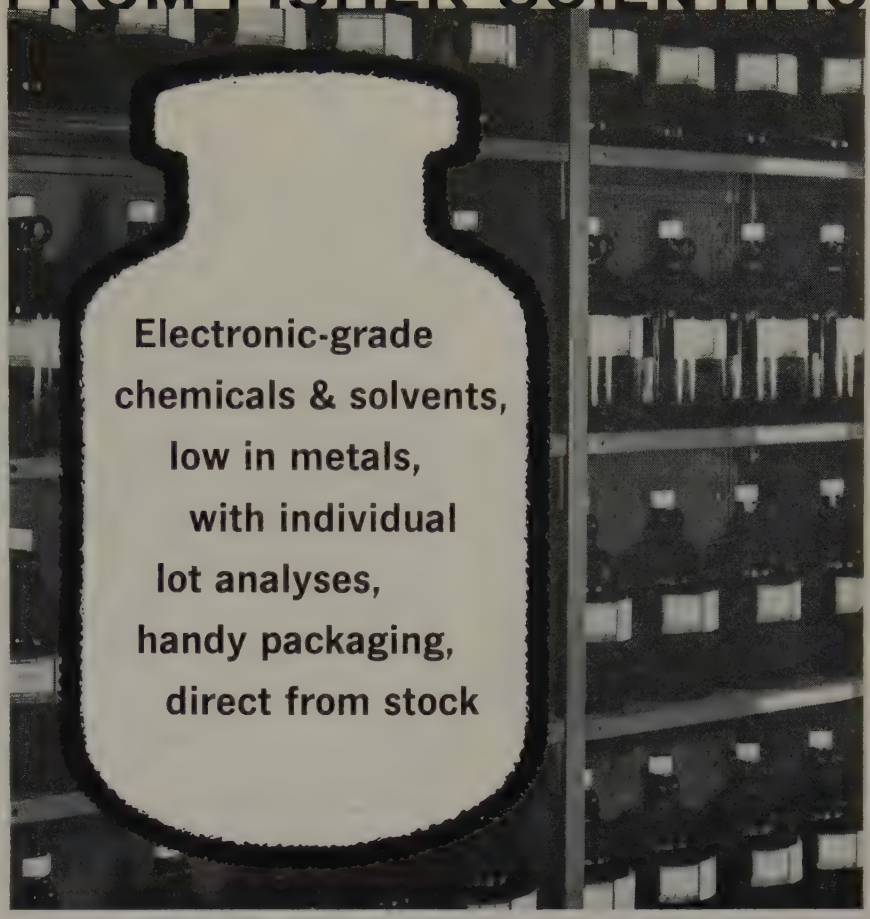

For use where unwanted metal atoms can upset electronic behavior of products, Fisher has developed 70 ultra-high purity chemicals and solvents, each bearing an individual lot analysis attesting to rigidly controlled purity. Attractively priced, conveniently packaged to your requirements in any quantities you specify. For data on **your** needs, write to the "Electronic Chemicals Dept., Fisher Scientific Co., 1 Reagent Lane, FairLawn, N.J."

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Ammonium chloride
Ammonium hydroxide
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Barium nitrate
Benzene
Boric acid
Cadmium chloride
Cadmium fluoborate 50%
Cadmium nitrate
Cadmium sulfate
Calcium carbonate
Calcium chloride
Calcium fluoride
Calcium nitrate
Calcium phosphate
Carbon tetrachloride
Cobalt carbonate
Cobalt oxide
Cobalt nitrate
Ether, anhydrous
Hydrochloric acid
Hydrofluoric acid
Hydrogen peroxide 3%, 30%
Lithium carbonate
Lithium chloride
Lithium nitrate
Lithium sulfate
Magnesium carbonate
Magnesium chloride
Magnesium oxide
Manganese dioxide
Manganese nitrate 50%
Manganous carbonate
Methanol
Nickel carbonate
Nickel oxide, black
Nickel oxide, green
Nickelous chloride
Nickelous nitrate
Nickelous sulfate
Nitric acid
Petroleum ether
Potassium dichromate
Potassium hydroxide
iso-Propyl alcohol
Silicic acid
Sodium carbonate
Sodium chloride
Sodium hydroxide
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Toluene
Trichloroethylene
Xylene
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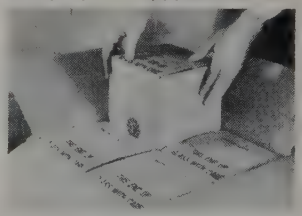
Zinc nitrate
Zinc oxide

Fisher solvents are safety-packed in shockproof-cartons, 4 gallons to a case.



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W. C. "BILL" PINE
Hayes Chief Metallurgist, reports on

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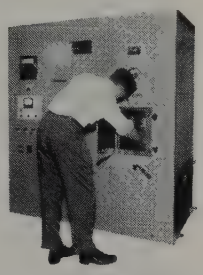
HIGH PRODUCTION RATES for alloying diodes, and brazing and outgassing tube components are assured with the new Hayes VAC-50 Series Cubicle Vacu-Master® — a compact, cold-wall vacuum furnace featuring full-size components consolidated into an attractive, space-saving cabinet. Also other outgassing and bake-out applications, as well.

IDEAL FOR SMALL JOB SHOPS, labs, and production lines where space is restricted, VAC-50 is an integrated package, ready to be installed anywhere, simply by hooking up water and power connections. (Standard size has 8" dia. x 14" deep work area.)

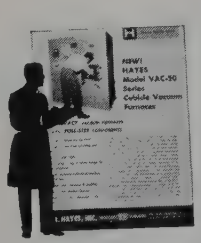


RAPID CYCLING is a big production plus. Max. temps. to 1200°C and vacuums to 10^{-4}, 10^{-5} mm. Hg. or lower can be developed in a matter of minutes, and cooling is almost as rapid. Versatile, too, the standard unit is easily modified by change of element, baffles, etc. for heats to 1800°C. max. (7" dia. x 12" deep work area).

SIMPLIFIED WORK HANDLING is built-in. Heating chamber door and operating controls are on front of panel. A manually operated pedestal transfers work load from lower cooling section to stainless steel heating chamber.

WIDE-OPEN ACCESSIBILITY through removable panels permits easy servicing. Fully-jacketed cold-wall furnace chamber prevents heat-up of auxiliary equipment, instruments, and surrounding area. Circuit is protected by automatic current limiting.

RESULTS GUARANTEED! The Hayes answer to your heat treat problem comes as a complete package . . . including free start-up service in your plant, and full instruction of your staff. Write today for Bulletin 6010B, to C. I. Hayes, Inc., 847 Wellington Ave., Cranston 10, Rhode Island.



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Circle No. 44 on Reader Service Card

New Literature

Semi-Alloys Inc. announces the availability of literature dealing with the melting point of alloys most commonly used in the fabrication of semiconductor products. The four basic alloys described are Aluminum, Gold, Indium and Silver, and depending on particular composition, the various melting points range from 29.8° C. to 1430° C. Alloying elements include, Boron, Gallium, Germanium, Antimony, Silicon, Tin, Silver, Aluminum, Lead, Cadmium, Phosphorus, Selenium, Tellurium, Magnesium, Arsenic, Nickel, Copper and Indium.

Circle 145 on Reader Service Card

Newly-issued two page data sheet #113 covering a 600 ampere surge test set that permits surge testing of silicon rectifiers in accordance with JAN specifications, is announced by Wallson Associates, Inc. The reference provides full information as to features, specifications and price.

Circle 146 on Reader Service Card

A "Semiconductor Selector Guide" which includes technical data on 43 devices for military applications, has been announced by Sylvania Electric Products Inc. The new 16-page brochure lists the mechanical construction and electrical ratings of every transistor, diode, rectifier, and microwave diode in the company's 500-type semiconductor line.

Circle 147 on Reader Service Card

An automatic organic spray coating machine for rapid, continuous finishing of electrical and electronic components having axial leads is described in a new brochure now available from Conforming Matrix Corporation.

Circle 148 on Reader Service Card

A new, 24-page, catalog of laboratory plastic ware is available from Will Corporation. The new brochure features plastic ware of all types: beakers, bottles, buckets, funnels, gloves, graduated cylinders, stirring apparatus, tubing, connectors, etc.

Circle 149 on Reader Service Card

Accurate Specialties Co., Inc., announces the availability of a new semiconductor alloy preform selector chart which lists 56 different alloys arranged in order of solidus and liquidus temperatures. The engineer can easily refer to the temperature range he is looking for and find which alloys are available.

Circle 150 on Reader Service Card

More than 150 different silicon diffused rectifiers are described in a new catalog offered by Raytheon Company's Semiconductor Division. Illustrations and complete mechanical and electrical specifications cover units ranging from 50 to 600 volts PIV and from 250 milliamperes to 22 amperes.

Circle 151 on Reader Service Card

RESEARCH BY SOVIET EXPERTS

TRANSLATED BY WESTERN SCIENTISTS

CONTEMPORARY PROBLEMS OF METALLURGY

Edited by A. H. Samarin

Published by Consultants Bureau for the Board of Governors of Acta Metallurgica under a grant from the National Science Foundation.

Offers Western scientists a comprehensive review of the most significant research and industrial applications in the field of metallurgy developed in the Soviet Union, China and East Germany.

530 pages $16.00

THE METALLURGY OF SEMICONDUCTORS

by Yu. M. Shashkov

In this up-to-date survey of semiconductor metallurgy, the two main semiconductor materials—germanium and silicon—and their physical and chemical properties are discussed. A detailed review of chemical methods of purifying these elements is followed by a description of metallurgical methods of purification.

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THE PHYSICAL BASIS OF POLARIZED EMISSION

(Polarized Luminescence of Atoms, Molecules, and Crystals)
by P. P. Feofilov

This is the first work to systematize the problems associated with the spectroscopy of polarized radiation.

Explanations of the phenomena under review are explored with the aid of concepts of the anisotropy of the elementary process of absorption and emission, based on the fundamental principles of both the classical and the quantum theory of radiation—one of the chief aims of the book being to establish the range of applicability of various basic theories.

appx. 288 pages $12.50

CONSULTANTS BUREAU
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Circle No. 45 on Reader Service Card

Written in catalog style, a new 12-page booklet gives a detailed presentation of Tektronix special-purpose test instruments. These include a direct-reading R-C Meter, an Indicator Unit, a Waveform Generator, 2 Pulse Generators, and Power Supplies. The booklet contains specifications, performance characteristics, pertinent illustrations for various measurement applications.

Circle 152 on Reader Service Card

General Electric Company has published a 96-page book on how to use tunnel diodes in electronic circuits. The new application manual is intended to be a reference source for circuit design engineers, and is similar to, and follows the pattern set by GE's Transistor Manual. The circuit application information is divided into four different chapters. These cover amplifiers, oscillators, switches, and logic circuits. In addition the Manual contains extensive chapters on tunnel diode ratings and characteristics and test circuits.

Circle 153 on Reader Service Card

Research Chemicals has just issued a revised data sheet and price listing on its rare earth metals. The revised data include the best current estimates of melting point and boiling point of the individual rare earth metals, as well as density and atomic radius constants. Prices are listed for quantities from 10 grams through pounds.

Circle 154 on Reader Service Card

A 12-page brochure describes a number of transistor testers of both the go no-go and absolute readout types designed and built by the Instrumentation Section of Fairchild Semiconductor Corporation. A description of typical testers and their salient features with test ranges, readout accuracy and resolution is presented in the brochure.

Circle 155 on Reader Service Card

The Sperry Semiconductor Division of Sperry Rand Corporation has issued a new spec sheet on five p-n-p silicon alloy junction transistors types 2N1219 through 2N1223. Comprehensive electrical data and characteristics are listed.

Circle 156 on Reader Service Card

A brochure from Owen Laboratories, Inc., describes Semiconductor Test Sets for use in circuit design and quality control. Testing of small, medium and large transistors, diodes, Zeners, SCRs, VJTs, switching devices, high current SCRs and rectifiers is covered in detail. Parameters that can be measured are also listed.

Circle 157 on Reader Service Card

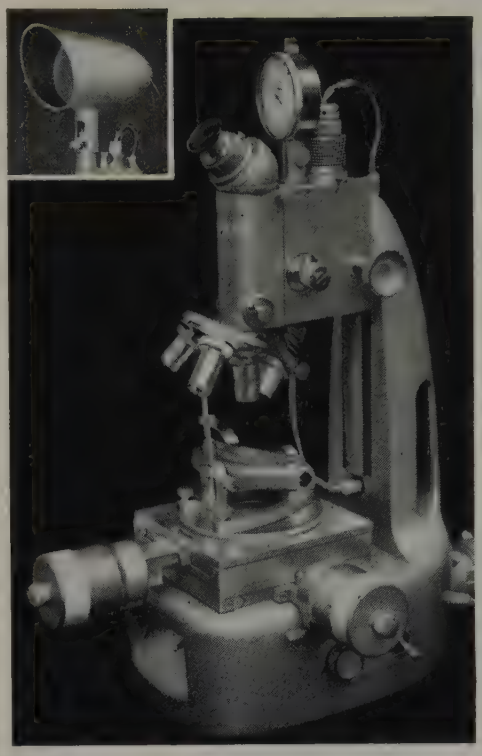
Electronic Research Associates, Inc., announces the availability of a new two color catalog sheet #122 which describes the company's recent additions to their high current Transpac line of miniaturized power packs. The catalog sheet provides full descriptive and technical information.

Circle 158 on Reader Service Card

Publication of a new catalog on high vacuum technology and products has been announced by the Vacuum Products Division, Varian Associates. The 16-page catalog is illustrated with photographs and diagrams.

Circle 159 on Reader Service Card

MEASURE TO 0.0001" IN 3 DIMENSIONS WITH UNITRON'S TOOLMAKERS MEASURING AND METALLURGICAL MICROSCOPE



The UNITRON Model TM is more than just a measuring microscope. It is the only instrument which combines in one stand a completely equipped toolmakers microscope for precise measurements — LENGTH, WIDTH and DEPTH, and a metallurgical microscope for examining the structure of polished metal samples under high magnification.

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- **Magnifications:** 30X, 100X, 400X; up to 2000X with accessories.
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- **Three Illuminators:** sub-stage, surface and vertical, have variable intensity.
- **Combination Stage:** rectangular ball bearing with linear measurements to 0.0001" and rotary measurements to 5' with vernier. (Metric model available on special order.)
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- **Eyepiece Turret:** available as accessory for measuring surfaces, radii, thread pitch etc.

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NEW SERVICE NOW AVAILABLE

SEMICONDUCTOR PRODUCTS is making a new source of information available to all firms interested in being kept up to date on materials or equipment for producing semiconductor devices. If you wish to receive all new literature on silicon, gremanium, chemicals, machinery, or other such materials, circle #99 on the reader-service card. Your name will be placed on a special list which will be forwarded to all such suppliers. As these suppliers have news available in their field, you'll be notified by them immediately. This service is restricted to firms manufacturing semiconductor devices or firms contemplating entering into production within 120 days.

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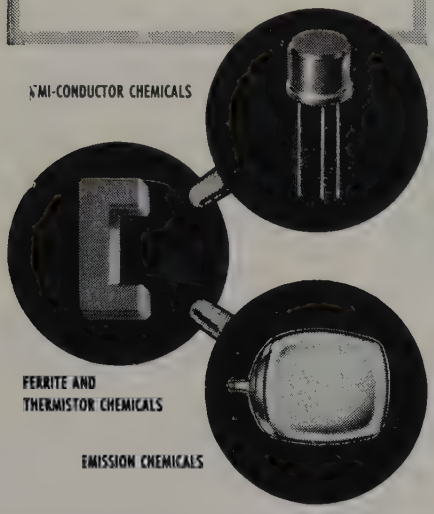

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IMPORTANT. 'Baker Analyzed' Reagents have consistently met or exceeded the requirements of the electronics industry. Through a continuing program of establishing additional and more stringent specifications, the *'Baker Analyzed' label consistently defines a degree of purity so high that special electronic labeling is unnecessary.*

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Phillipsburg, New Jersey

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Personnel Notes

Kahle Engineering, designers and builders of machinery for the electronics industry, announces that William T. Engel has been appointed Chief Engineer, in charge of the Engineering & Design Department.

The appointment of William R. Weir to the newly-created position of national sales manager for the Semiconductor Division of Sylvania Electric Products Inc., Woburn, Mass., has been announced by Ernest H. Ulm, general marketing manager for the division.

The following appointments for Allied Chemical's General Chemical Division have been announced by James W. Swaine, vice president. All are headquartered at the Camden, N. J. Engineering Department. James M. Jans, assistant chief engineer for the past 13 years, has been named chief engineer. Reporting directly to him are: Robert G. Bierbower, manager of engineering administration, John L. Ciba, manager of design engineering, Charles W. Gaylord, manager of process engineering, James Jaffe, manager of process engineering.

Dr. Herbert E. Morris, director of the Boston Laboratories of Monsanto Research Corporation at Everett, Mass., has been appointed technical director of the corporation effective immediately, Howard K. Nason, MRC president. announced recently.

Appointment of Edgar Pollacek as supervisor of sales for industrial selenium rectifiers manufactured by the Selenium Division of Radio Receptor Company, subsidiary of General Instrument Corporation, is announced by Arno Nash, Vice President and General Manager of the Division.

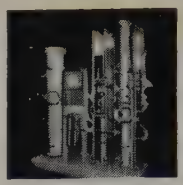
Thomas D. Bushman has been appointed Product Manager of Semiconductor Processing Equipment at Norton Company's Machine Tool Division. In this position, he will be responsible for developing and coordinating sales of the newly announced line of machines for the slicing and lapping of materials such as germanium and silicon used in making transistors and similar electronic products.

Promotion of two sales executives at Hevi-Duty Electric Company, Watertown, Wis., has been announced by General Sales Manager A. W. Frank. R. G. Martinek has been named product sales manager of the firm's five furnace and oven product lines. C. A. Newton has become product manager of the light industrial furnace line.

Standard Rectifier Corporation, Santa Ana, Calif., recently announced the appointment of Fred Troy as West Coast district sales manager, according to Ted Phillips, national sales manager.

Election of Frank F. Cleminshaw as Treasurer of General Instrument Corporation was announced by Board Chairman Martin H. Benedek.

Demineralizing Equipment NEWS from Penfield



Fully "Packaged" System Supplies 125-150 GPH of 18 Megohm Water

Penfield's new S-150 Demineralizing System includes multiple influent filters to remove turbidi master dual-column demineralizer, scavenging ca bon filter, polishing mono-column demineralize sub-micron effluent filter — all completely "pa aged" on a single skid, ready to deliver effluent of 18 megohms and better upon simp connection to service lines. (Other fully "pac aged" Penfield systems available with capaciti from 60 to 10,000 GPH.)

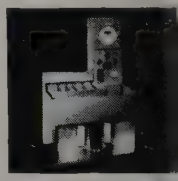
Pressure-Type Demineralizer "Polishes" to Ultra-High Purity at Point-of-Use

The Penfield PM-8 Demineralizer supplies up to 5 GPH of 18-22 megohm water — is ideal for point-of-use "polishing." Permanent cartridge desig prevents raw water by-pass experienced wit "canned" resin units. Cartridge unscrews by hand to permit easy resin renewal from bulk supplies enabling substantial savings in replacement resin costs. Unit also can be charged for use as cation exchanger, anion exchanger, carbon filter oxygen or organic remover, and is adaptable fo scavenging oil from gases.

In-Plant Regeneration Unit Saves 90% of Costs of Demineralized Water

A Penfield Regeneration Unit makes the renewa of exhausted resins from Point-of-Use Demineralizers an easy in-plant function. Operator merely feeds resin into unit, then turns a single master switch to control resin separation, regeneration rinsing and proper re-mixing. Average operating cost, including all labor and regenerants, is less than 30c per cartridge.

Fully Integrated Weir Washer "Polishes," Heats, Monitors, Cascading Water



Integral filters and pressure-type demineralizers enable circulation of 18-22 megohm water through multiple partitioned tank of a special weir design that precludes stagnation. Direct reading conductivity meter permits instant monitoring at any of three check points. Novel clip bar makes replacing heat elements simple. (Penfield also constructs weir washer tanks in standard sizes or to customer specifications, using a wide variety of materials such as block tin, cast acrylic plastic, etc.)

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Circle No. 48 on Reader Service Card

Philco Corporation has announced the appointment of Thomas J. Anthony as a regional sales engineer for the Lansdale division's semiconductor operations. Semiconductor sales manager, William F. Maher explained that Mr. Anthony has been assigned to the division's southwest regional office located at 310 South Bumby Street, Orlando, Florida.

Frederick R. Lack has been named to the newly created post of senior vice president in charge of research of the Sprague Electric Company, it was announced by Robert C. Sprague, chairman of the board and chief executive officer. Election of Mr. Lack by the Board of Directors followed the annual meeting of stockholders at which Neal W. Welch and Dr. Wilbur A. Lazier were added to the board to expand its membership to twelve.

Joseph Almeida has been appointed a district sales manager for the General Electric Company's Semiconductor Products Department, Syracuse, N. Y. He will call on original equipment manufacturers in Virginia and North Carolina from sales offices in the company's Carroll Ave. plant, Lynchburg, Va.

Lester Avnet, president of Avnet Electronics Corporation, announced the following executive promotions: Myron Newberger, President of Avnet Corporation, west coast subsidiary; Daniel J. D'Addario, general manager of east coast operations.

Dr. Bernd Ross has rejoined the Semiconductor Division of Hoffman Electronics Corporation as manager of the solar development section and assistant technical director, Dr. Morton B. Prince, vice president and division manager, announced recently.

Maurice E. Dumesnil has joined the technical staff of Fairchild Semiconductor Corporation's Research & Development Laboratories. Mr. Dumesnil has been assigned to the Chemistry Section where he will conduct research in glass, ceramics and related fields with respect to their use in the semiconductor industry.

John E. Locke has been appointed manager of diode operations for the semiconductor division of Hughes Aircraft Company, it was announced by David A. Hill, division manager. He previously was director of administration and assistant to the vice-president of the company's components group.

G. William DeSousa, Marketing Manager, Sperry Semiconductor Division announced the appointment of Jesse G. Moore as General Sales Manager, a new position with the Division. Mr. Moore will be responsible for all OEM, distributor, and international sales of this Division.

CBS Laboratories has consolidated its activities in solid state physics, and Dr. Wolfgang W. Gaertner has been promoted to Vice President in charge of this area, Dr. Peter C. Goldmark, President and Director of Research, announced recently. The Laboratories is a division of Columbia Broadcasting System, Inc., and is located in Stamford, Conn.

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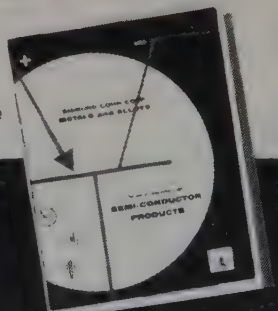
Platinum Alloy Ribbon



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by George T. Sermon, President
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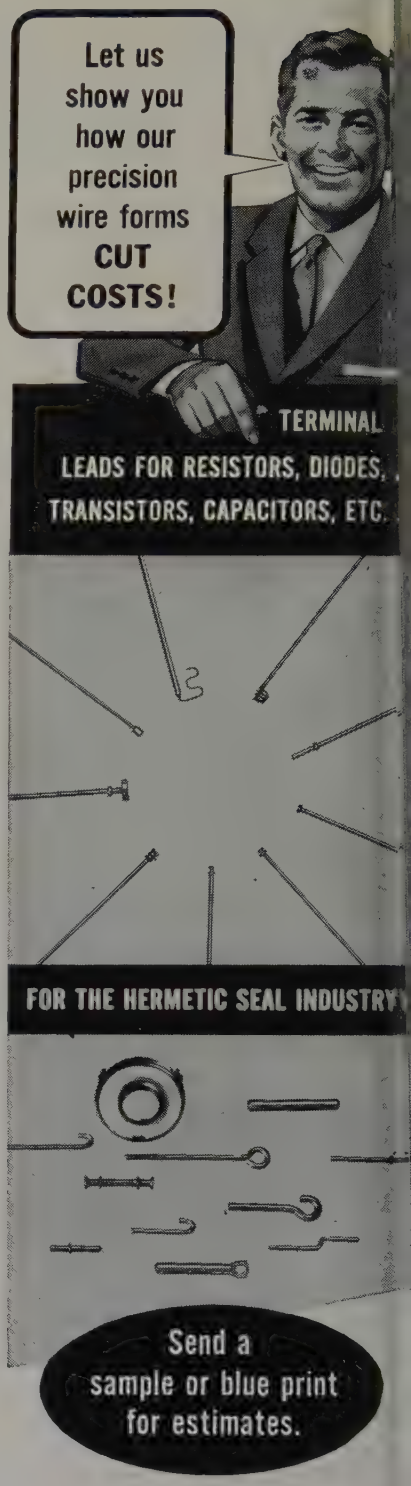
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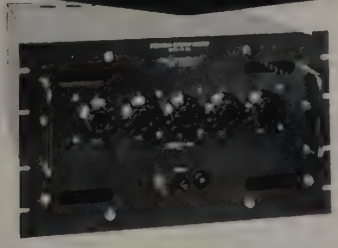

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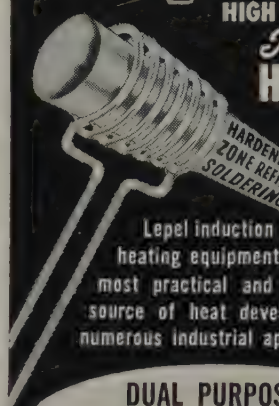

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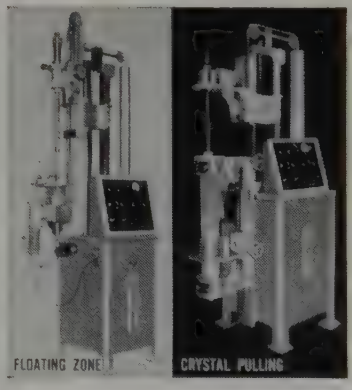

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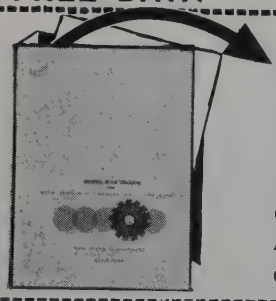

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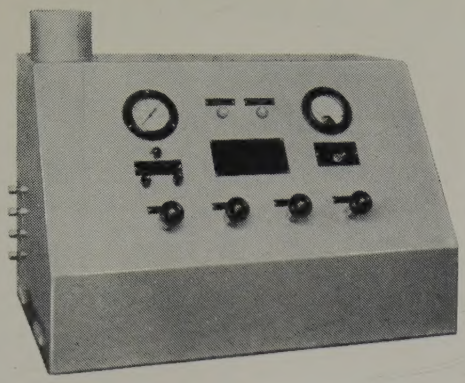

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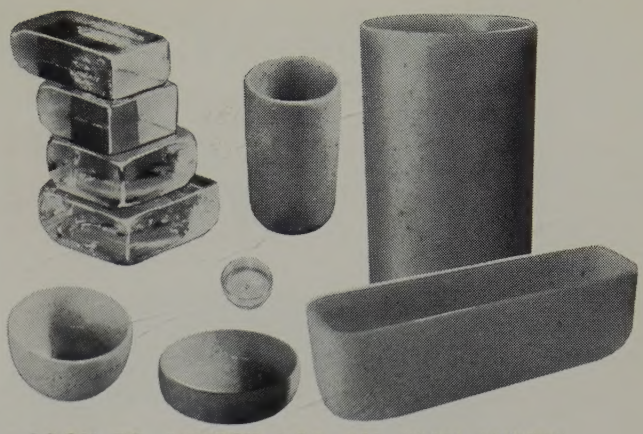

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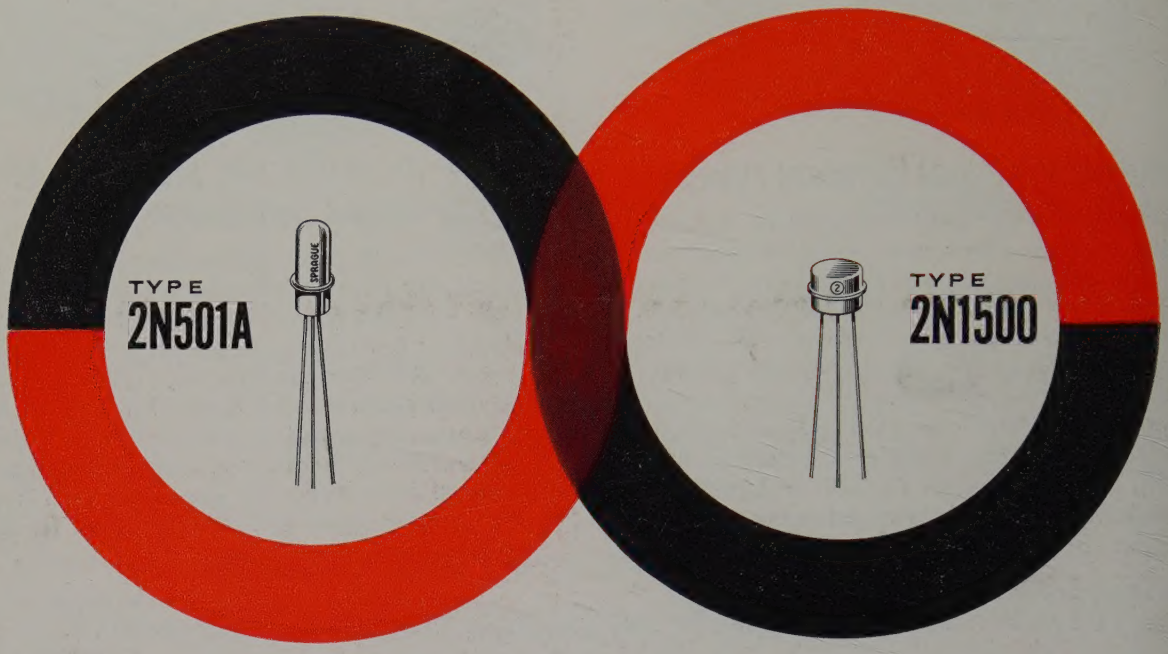

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